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Collaborating Environmental Disciplines

An Analysis of Social and Technological Factors Regarding Ecological Engineering

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Letter of Transmittal

December 15, 1998

Dr. Edward Bryan
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Dr. Bryan:

Enclosed is our report entitled ***Collaborating Environmental Disciplines,*** *an analysis of social and technological factors in ecological engineering with regards to contaminated sediment in the Baltimore area of the Chesapeake Bay*. It was written at the National Science Foundation during the late Autumn of 1998 (October 26th through December 15th). Preliminary work was completed in Worcester, Massachusetts at Worcester Polytechnic Institute, prior to our arrival in Washington D.C. Copies of this report are simultaneously being submitted to Prof. Susan Vernon-Gerstenfeld, Prof. Chrys Demetry, and Prof. Angel Rivera for evaluation. Upon faculty review, the original copy of this report will be cataloged in the Gordon Library at WPI. We appreciate your time, concern, and help with us on our project.

Sincerely,

Simon Nance Richard C. Bradshaw Uri Braun

Title Sheet

Report Submitted to
Chrys Demetry
Angel Rivera
Washington DC Project Center
By

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In Cooperation With

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National Science Foundation:
Engineering Directorate: Bioengineering and Environmental Systems Division:
Environmental / Ocean Systems Program

COLLABORATING ENVIRONMENTAL DISCIPLINES

AN ANALYSIS OF SOCIAL AND TECHNOLOGICAL FACTORS IN ECOLOGICAL ENGINEERING WITH REGARDS TO CONTAMINATED SEDIMENT IN THE BALTIMORE AREA OF THE CHESAPEAKE BAY

December 15, 1998

Abstract

With support from the National Science Foundation, the effective collaboration of facets within ecological engineering was analyzed. Using the case study of Chesapeake Bay contaminated sediment, the unity, sustainability, and future direction of all ecological engineering's disciplines – environmental engineering, environmental technology, appropriate technology, and industrial ecology – were analyzed and described, and directions of focus were recommended. This single case study was used as a concrete example for our far-reaching analysis of the above disciplines within ecological engineering.

Authorship Page

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Acknowledgements

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1.0 Executive Summary

Because of continuing environmental, societal, and technological changes, there is a need for understanding the future direction of many concepts in the environmental fields. This report, regarding those issues, was developed through archival research, interviews, and discussions, and is a degree requirement for its creators in their academic studies at Worcester Polytechnic Institute. Working with the National Science Foundation's Directorate for Engineering in their Bioengineering and Environmental Systems Division, this report was developed using a case study of contaminated sediment creation and removal in the Baltimore area of the Chesapeake Bay in order to address the future direction and sustainability of ecological engineering in all of its facets.

In order to understand certain terms and concepts of our analysis, the issues with which we are concerned must be clarified. Using pertinent literature, archival research, and personal interviews, the disciplines of ecological engineering, environmental engineering, environmental technology, appropriate technology and industrial ecology were addressed; their brief definitions are as follows:

> *Ecological engineering* is a perspective or a systems approach to environmental management, which ties the environment and local society in a conscious symbiotic relationship, sharing costs and benefits. This approach encompasses many other social, technological, and scientific disciplines including the four following.
>
> *Environmental engineering* is the use of methods to discover and solve pollution problems such as waste management and pollution treatment.

Environmental technology involves the use of new scientific applications and tools to prevent pollution problems; this includes alternative energies and resources.

Appropriate technology involves those technologies fitting to the local social, regional, economic, and environmental situations.

Industrial ecology is simply a cyclical pattern of wastes as raw materials usage by neighboring industries to create a low materials cost and pollution free region.

With these parameters set, an analysis of the sediment removal case study in the Chesapeake Bay will show the interrelations of these disciplines, their mutual strides toward a sustainable future, and their hindrances. Our analysis demonstrates that all areas considered to be part of ecological engineering are molding together in a way that makes them interdependent. Unfortunately, due to three factors: technology / terminology, public opinion, and policy / economics, the progress to effective futures of these areas is possibly limited.

It is the reformulation of the above three factors that will give sustainability to the interdependence of environmental disciplines. First, it is seen that no matter how useful or beneficial certain technologies and methods in ecological engineering, progress toward applicable solutions in any of these disciplines is impossible without the support of local public opinion. This is shown in the lack of public support of ecological solutions such as the Hart-Miller Island project or other innovations of which the public has little awareness or understanding.

Second, it becomes apparent that current policies, especially social, economic, political, and legislative policy, tend to encumber rather than facilitate the progress of environmental disciplines. This is due in large part to three factors: complexity, visibility, and incompatibility. Complexities are inherent in the ecosystem and in our interactions with it; therefore, they present certain problems such as incongruence of time periods of study. The lack of visibility and awareness of the extent of those problems – that is, the lack of public knowledge – reduces progress in solving them. Beyond complexity and visibility, many factors exist which make it difficult to unite environmental concerns with current social, economic, and political values. In addition to the problems already mentioned, it is difficult to put a monetary value on a local environmental ecosystem.

Finally, and perhaps most importantly, there is a lack of coordination between various groups who have direct influence on the out come of the Chesapeake Bay. This problem comes from a lack of agreement in terminology definitions. Before large-scale progress in dealing with contaminated sediment can occur, this void must be filled. A primary example of this is the definition of contaminated sediment – it varies. Does contaminated mean unfit for human use, or does it simply mean containing alien particles? Without a clear definition, the proper technology needed for its disposal or reuse remains vague. A current disposal site is Hart-Miller Island, but it is unclear as to whether the sediment it contains is actually "contaminated."

From the above three points of analysis, it can be concluded that a certain level of collaboration exists among fields within ecological engineering on a technological and analytical level, but a lack of mutual understanding of these connections is a severe hindrance. This knowledge barrier prevents the development and sustainability of a mutually agreeable future among ecological engineering disciplines. Our recommendations are, therefore, concerning improvements in education and communication. The National Science Foundation can give support to those elements by aiding projects that promote public ecological education, industrial cooperation, and local public awareness, responsibility, and involvement.

2.0 Introduction

2.1 Problems and Solutions

Unfortunately, “modern man does not experience himself as a part of nature, but as an outside force destined to dominate and conquer it,” (Ernst Shoemaker, 1973). Over time, the damage caused by this egocentric mentality has become more and more evident, but we are an integral part of our planet, and as such, we must acknowledge the damage we have, and take the responsibility of reparations and prevention of future disaster. Now faced with fixing environmental problems and preventing their repetition, there are major hurdles facing the next generation. What are the causes and effects of these barriers? What tools must we develop now to enable us to clear those hurdles when we come to them?

Discontinuing existing practices, even if it were possible, would be insufficient. Impact from environmentally harmful habits often take years before their full impact is felt; therefore, progress will require not only minimizing future destruction but also reversing existing destruction to counteract damage from actions already completed but whose impact has not yet been fully felt. This project will analyze, describe, and recommend to the National Science Foundation directions of focus concerning the interactions, sustainability, and future direction of ecological engineering in all of its facets – environmental engineering, environmental technology, appropriate technology, industrial ecology. Our analysis will answer some of these questions.

2.2 Our Purpose

It becomes increasingly apparent today, with advancements in social and technological sciences, that there are definite overlaps in all fields of science and engineering. Ecological engineering is no exception to this trend. Communication both within ecological engineering and with related disciplines would be greatly enhanced if the terms used were clearly described and well understood. This project seeks to understand these terms and study how they interrelate. Specifically, it will address the interactions of environmental engineering, environmental technology, appropriate technology and industrial ecology.

The study of these interactions is broad and encompassing; therefore, we added a case study to focus the topic. In consideration of our seven-week time constraint, we will be examining the issues associated with contaminated sediment removal and disposal in the Chesapeake Bay in conjunction with ecological engineering disciplines. Because dredging and sediment disposal has the potential to reintroduce contaminants into surrounding ecological systems as well as create social, economic, and environmental problems through its disposal, the dredging issue in the Chesapeake Bay area is an ideal case study for the analysis of the interrelations in the many facets of ecological engineering.

The Bioengineering and Environmental Systems Division of the National Science Foundation aids research and implementation of environmentally conscious technologies throughout the United States. Future studies will involve issues in environmental engineering, environmental technology, industrial ecology, and appropriate technology. Having a somewhat transitory status over the years, these four areas of ecological engineering may bring confusion to present researchers. Using the case study of dredging in the Chesapeake Bay, we will analyze the unity, sustainability, and future direction of ecological engineering in all of its facets. This report seeks to improve the rate of progress in ecological engineering disciplines by making recommendations which will allow for greater collaboration among those disciplines and will sustain that collaboration through improvements in social, organizational, economic, and technical aspects of those disciplines.

2.3 Dredging in the Chesapeake Bay

Since the Chesapeake Bay is being dredged for navigation purposes, the problem of dealing with the removed sediment – especially that which is contaminated – is a current issue. The pollution problems are not only in the removal of the contaminated sediment from the bottom of the Bay. Once the sediment has been brought to the surface the remaining difficulty is how to properly deal with the contaminated sediment. Because it is a major regional concern and has extensive involvement from numerous organizations, agencies, and companies, our Chesapeake Bay contaminated dredge spoils analysis is an ideal example of interactions within ecological engineering.

As stated above, this project is analyzing links among the disciplines of ecological engineering; the dredging issue in the Chesapeake Bay provides a case study, with which all of the ecological topics addressed can be examined. Hence, dredging in the Chesapeake Bay will be our primary case study used for examples and analysis for this project.

2.4 Student Requirement and Outside Support

The analysis described above is exemplary of the interactions between society and technology and is therefore appropriate as an Interactive Qualifying Project. This report will be used by the students from Worcester Polytechnic Institute (WPI) to partially fulfill WPI's undergraduate degree requirement of successful participation in an Interactive Qualifying Project (IQP). Completion of an IQP is intended to teach students about the interaction between society and technology. By anticipating the needs of society and identifying the needed technological advancements, completion of this project fulfills the requirement. This project was made possible through the support of the National Science Foundation situated in Arlington, Virginia. The National Science Foundation's mission is to promote science, mathematics and engineering and to encourage the use of that knowledge in ways that benefit society; the recommendations in this project are in accordance with that mission.

3.0 Literature Review

3.1 Ecological Engineering

Ecological engineering is a systems approach to environmental management that considers the environment as a significant and participating agent in its own preservation. Unlike many other approaches, both human society and the natural environment are considered to be in a symbiotic relationship where both help solve the problem and both reap the benefits of that solution. Another outcome of the ecological engineering perspective of environmental management is that it encompasses many aspects from other scientific, technological, and social disciplines and even those disciplines in their entirety.

Historically the goal of environmental management has been "zero impact". Under such a model, society would seek to intercept any and all impacts on the environment. Preservation would be accomplished through protection and isolation. The idea was leaving as much of the environment as possible unaffected by human activity (Mitsch, 1989).

Principles of ecological engineering consider such a zero impact mission impossible or at least prohibitively expensive. Instead, the goal should be a partnership in which both society and the environment benefit; the environment becomes a source of solutions rather than just an independent system. Through a symbiotic interdependent relationship, society uses the environment to convert wastes into raw materials and in the process preserves the environment and provides it with necessary conditions for its survival. The environment's preservation is secured as a result of its critical role in the system (Mitsch, 1989)

Such a continuous interplay between humans and their surrounding environment is made possible partially through science and engineering effort. Specific disciplines such as environmental engineering, environmental technology, industrial ecology, and appropriate technology are part of this interplay. Environmental engineering shows humans their negative environmental impact as well as possible solutions to this impact; environmental technology emphasizes preventative measures. Appropriate technologies allow humans to manage their environmental interactions by developing suitable applications for specific situations. Industrial ecology promotes interplay of humans, their natural environments, and their man-made commercial and industrial environments by helping industries work together for minimum negative environmental impact (Allenby, 1999). These disciplines of ecological engineering are further described in the following section.

3.2 Environmental Engineering

Definitions for environmental engineering vary from field to field and from source to source. For our purposes, environmental engineering is defined as the branch of engineering that studies the impact of humans on the environment and develops techniques to minimize negative effects (Britannica, 1998). A more in depth definition could be phrased as the synthesis of infrastructures to manage water supplies, waste management and pollution control. Environmental engineering tends to use an ecosystem – that small piece of the environment under study including all flora, fauna, and geological systems within it – as a basic unit of the environment. The study of these ecosystems, or ecology, is the study of organisms and the relationship with their environment. (Funk & Wagnalls New Encyclopedia, 1983).

3.2.1 Origins of Environmental Engineering

Over twenty years of environmental engineering ideas have led us to present techniques for water purification, recycling, and energy production. Many of these ideas and concepts were spawned out of the Soviet-U.S. space race and the 1970's Arab oil embargo (Moore, 1994). When the Soviet Union roared into a commanding lead over the American space program with the successful launching and orbiting of the Sputnik space probe, the American response was to initiate a technology race for command of the space frontier. What this technology race brought about were numerous environmentally friendly technologies. Technologies ranging from advanced solar panels to hydrogen oxygen fuel cells were developed for space travel (Moore, 1994). Solar panels aid us in reducing the amount of fossil fuels consumed to make electricity. Other creations such as advanced plastics helped industries develop more efficient manufacturing processes, which in turn reduced certain waste materials.

After the space race had all but subsided the Arab oil crisis in 1973, there spurred another round of more new efficient technologies from which the environment benefited. Technologies such as fuel-efficient injection systems in cars and improved catalytic converters that reduce car emissions evolved out of the oil shortage. As a direct result of these two catalysts the U.S. was by the mid 1980's the world's leader in the development of environmental technologies (Moore, 1994). But, as a result of lack of direction in this field, the U.S. quickly lost its technological leadership role through capitalistic ventures by other countries, such as Japan, Germany and Canada (Moore, 1994).

3.2.2 Fundamentals of Environmental Engineering

Because environmental engineering pertains to humans' effects on the environment, waste management, pollution control, energy production, and ecosystem obstruction are the fields on which environmental engineers concentrate. Waste management deals mostly with recycling and toxic materials. Pollution control pertains to clean up efforts and prevention tactics such as designing processes with recyclable byproducts, while water purification would be possibly located under obstruction of ecosystems. Examples of pollution control are scrubbers (toxin absorption systems) in industrial smoke stacks and enzyme treatment of wastewater. An example of energy production is the development of fuel cells and flywheel batteries (renewable energy resources). A key goal behind environmental engineering is attempting to create better non-polluting products while increasing efficiency and economic sales (Kincaid, 1996).

Waste management technologies deal typically with end of pipe situations were the waste has already been produced and then that waste has to be dealt with in some manner, whether it be dumping it or turning it into fuel. These technologies may cover everything from how to clean air pollutants out of exhaust fumes to the proper disposal practices for landfills (Orszulik, 1997). A good example is the oil industries' design for sludge handling where the industry may do one of many things. Sometimes the sludge will be burned off for energy, recycled, and sometimes is used for land farming (Orszulik, 1997).

Pollution control, the other field dealt with by environmental engineers, is sometimes end of pipe environmental technology. Pollution control will very often start at the beginning of a process – usually an area in which the field of environmental technology resides – by doing things as simple as reducing the amount of fuel used for power generation or perhaps the type of fuel. There are end of pipe technologies as well, such as smoke stack scrubbers and wastewater treatments, mentioned above (Billatos, 1997).

Energy Production, also an environmental engineer's issue, may go hand in hand with pollution control or prevention. Solar panels are an excellent example of this type of technological approach. The solar panels produce no waste at all, beginning or end; only good clean energy is achieved (International Energy Agency, 1996). Since all technologies are not created to support the environment, we and our natural surroundings (our human ecosystems) are damaged. Ecosystem obstruction is the area in which a technology has failed to take into account the surrounding ecosystem and is either hindering or destroying.

3.2.3 Present Status of Environmental Engineering

Green engineering or green technologies are other terms for environmental engineering (Billatos, 1997). Since all engineering fields support methods and technologies that are somehow profitable, environmental engineering developments have gained a substantial market. With several different names creating a loosely defined field to study, it is hard to tell, from an economic sense, where this area stands in the world. But rough estimates done by the Environmental Protection Agency predict that on average this arena draws in over $170 Billion a year (Moore, 1994). Although, as was described earlier, the U.S. is not entirely responsible for this due to its loss of control of many of the technologies it developed (Moore, 1994).

3.3 Environmental Technology

Environmental Technology is the implementation of Environmental Engineering. The term is now being associated more and more with the products that are produced out of the green technology movement (Moore, 1994). Environmental Technology is not only used for consumer products, but also in manufacturing processes. These environmentally friendly manufacturing processes range from reduction of energy consumption to containment of toxins when mining. Unfortunately, due to misinformation, many businesses shy away from the idea of environmental technologies due to the fact that many feel that it will be a long term costly endeavor with few benefits (Billatos, 1997).

3.3.1 Origins of Environmental Technologies

Environmental technologies, also known as "green" technologies, were drawn into the spotlight during the environmental movements of the 1970's. These movements began with that era's rebellious youths and gained in popularity until even large industries became involved. Although existing for quite some time (green technologies include innovations as simple as mercury-free batteries), the high levels of consumption and waste thirty years ago pushed for their further development (Billatos, 1997). Along with research and development of newer environmental technologies, legislation and regulations developed. Companies such as Selectria, Dow Chemicals, Gore Associates, Costner Enterprises, Saturn, and many more either developed or reengineered because of this environmental technologies movement.

3.3.2 Fundamentals of Environmental Technology

According to many experts, energy production from renewable resources is often more reliable, cheaper, and of higher quality than traditional production techniques. As new technologies are becoming available, the cost related to reducing wasted energy and using renewable resources is quickly becoming more economically viable than the current method of simply increasing centralized production. From refrigerators, which cut energy use by more than eighty percent, to washing machines that cut water use by as much as two-thirds, waste reduction through increased efficiency is quickly becoming the cheapest way to reduce energy costs. Similar improvements in energy production from renewable resources are revolutionizing energy production methods. Renewable resources are now the fast growing energy source in Europe. Wind power resources are growing at over twenty five percent a year worldwide and solar has been growing at about forty percent. (Flaton, 1998; Saxenian and Darrow, 1986)

3.3.3 Present Status of Environmental Technology

The present day status of environmental or green technologies ranges from manufacturing processes, as stated above, to genetic engineering. Stemming from ideas of green technology, companies as far reaching as Ben and Jerry's and The Body Shop (with their "all organic" approaches) have been able to profit (Moore, 1994). An example of environmental technologies in genetics is a current study being done to determine the feasibility of using genetically altered trees to clean contaminated soils (Verrengia, 1998).

3.4 Industrial Ecology

Industrial ecology is the on going process of trying to achieve a closed cycle where energy consumption, products, and byproducts remain in a single industrial system. One of the main tools to obtain this goal is to apply current sciences or conservation technologies. Conservation technologies are the development or planned management of a natural resource or the total environment of a particular ecosystem to provide guidance for the use of that resource or ecosystem. This guidance helps to ensure that the resource and or ecosystem will continue to exist in a healthy state so that it can still be used for industrial gain (Lowe, 1997).

The fast past growth of industrial technologies sometimes bypasses the concept of conservation thus creating conflicts with movement toward a completely closed industrial ecology. A good example of this is Great Britain's optimism in the late 1960's about developing and harnessing alternate energy resources, nuclear power and natural gas found in the North Sea, resources that would possibly wean England away from oil dependence. But due to increased industrial progression within five years Britain was more dependent on oil than ever. Instead of waiting for the technology that would help close the ecological cycle, uncontrolled progress got in the way of conservation (Schumacher, 1973). Technology brings us great advantages although with its helpful advances can come misuse and mismanagement when relating to environmental concerns. On the converse, if technology brings us quick short-term solutions to environmental problems, it can also bring unknown long-term side effects. The reason being, these technologies are introduced into a balanced system and with an added time factor, can imbalance the system and cause a break down. Although this is usually unintentional and originally meant to help with a problem, the result may still be the loss of the human resource or environment. Examples of such situations include the polluting effects of certain industries or the spread of waterborne diseases following the construction of major irrigation projects (Britannica, 1998).

3.4.1 Origins of Industrial Ecology

The concept of Industrial ecology is not a new one. It has existed in one form or another from the beginning of the industrial revolution where to the early Ford motor factories that pumped their factories' exhaust back under the factory in large tubes to reclaim the heat energy from the exhaust, to heat the factory, before exiting. Today's industrial ecology standards and driving forces are primarily originating from the International Standards Organization – the group responsible or international industrial standards regulations (Noonan, 1998). The driving forces arising due to the inclusion of new environmental specifications with the change from ISO 9000 to ISO 14000 – industrial standards policies – industries are now being pressured to provide Environmental Management System designs and Life Cycle Analysis (Noonan, 1998).

3.4.2 Fundamentals of Industrial Ecology

Many engineering projects have been done in the past to aid in reversing the effects of many industries' negative environmental impacts. Industrial Ecology is a systems based approach to studying the effects of human activity on the environment Its mission is to maintain a sustainable environment while keeping human impact to a minimum and protecting the quality of life. The major difference between the industrial ecology's systems approach and more traditional approaches to the environment is the focus on looking at the entire system. If the environment is to be preserved, increasing the rate of production requires an increased consumption of the byproducts. Moving to the sustainable development model described by industrial ecology presents many opportunities for business and government.

Business will have opportunities to cut costs and generate new revenues. Wastes may become a source of income as they are sold as raw material used to produce another product. Although they are termed "wastes," these products, if reused, must meet certain quality standards (depending on the industry). The "waste" material may even be of better quality or easier to manufacture than other raw materials. This may also cut costs since the "waste" produced as a byproduct of another product may replace costly raw materials. By creating a cycle in which "wastes" as raw materials the amount of raw material produced is reduced and the amount of "waste" not utilized can be significantly reduced (Allenby, 1999).

In order for the life cycle of an industrial process to be analyzed, an evaluation must be designed. One of the steps in this design process is developing a mathematical model of the situation. For example, in the Exxon-Valdez oil spill, new cleaning methods proposed helped accelerate the recovery process, once the initial clean up of the coastline was under way. One of the methods proposed was to use fertilizers to boost naturally occurring bacteria's performance at processing the spilled oil through natural processes, known as bioremediation (Lung, 1993). Individuals raised questions regarding the long-term impact of the fertilizers on the region. To help predict this impact and suggest amounts of fertilizers to be used, scientists needed mathematical models. The models used in this particular situation were needed to help predict salinity and pH levels in the surrounding waters in relation to glacial melt run off into the bays and inlets (Lung, 1993).

Scientists can use mathematical modeling to help in the analysis of a clean up approach. There are many other uses for this tool, such as predicting the behavior of a system. For example, mathematical modeling can be used to predict eutrophication of a given body of water. To properly select a spot to begin a coastal fish farm, guidelines such as ecological parameters, weather of the region, and how well the body of water cycles itself through the area must be taken into account; this way, reliable models are developed (Lee, 1997). Different models will exist for every situation. Sometimes these models are developed specifically for such situations; other times standardized models will be adapted. An example of modeling for water quality would be the Gauss-Seidel method and difference approximations (Hwang, 1996).

3.4.3 Present Status of Industrial Ecology

Businesses are finding that by designing products and processes with the environment in mind, they can reduce the environmental impacts of the products and services our society now enjoys, which improves profitability and the quality of life while strengthening the economy (Kincaid, 1996). Predictions for the next decade and beyond say that with the increase in population and thus the increase in industrial processes, the environmental impact could increase by a factor of 10 to 20 (Klostermann,1998). To help combat this extreme increase, experts such as A. B. Lovins and L. H. Lovins have proposed to stimulate a reduction of environmental impact by these factors. The goal would be to reduce by a factor of four on a set time interval to achieve the recommended reductions (Klostermann).

3.5 Appropriate Technology

Appropriate technologies are those scientific advancements that are fitting to specific situations. Certain elements of these advancements bring forth appropriateness (that which is fitting to the situation). First, they usually require only small amounts of capital and emphasize the use of locally available materials, in order to lower costs and reduce supply problems. For the most part (and especially in third world countries where they are a large concern) appropriate technologies are small enough in scale to be affordable to individual families or small groups of families and can be maintained by these individuals without a high level of special training. Most importantly, they are flexible enough to be adapted to different places and changing circumstances and can be used in productive ways without doing harm to the environment (Darrow, 1986).

3.5.1 Origins of Appropriate Technology

Appropriate, or applied, technology has been an idea since the creation of the first tools used by man so its origins lie in the ideas of technology itself. The modern holistic view of appropriate technology can most likely be attributed to Ernst Schumacher and his intertwining of social philosophy and economics in his book Small is Beautiful. In it, he defines six "large" ideas, concerning education, which leads to the relationship between people and their social and technological environment. First there is the idea of evolution – the idea that higher forms continually develop out of lower forms. Second, he brings forth the concepts of competition, natural selection, and survival of the fittest, which give reasons for the above idea of evolution. Higher "manifestations of human life," for example: religion, philosophy, art, etc., are the third idea. This leads into the idea that those manifestations are not actual, but subconscious. Fifth is the general idea of relativism, a view of alternative standpoints which denies all absolutes and dissolves all norms and standards. Finally, there is the "triumphant" idea of "positivism," the idea that all knowledge's validity is based on observable facts. These six ideas based on general education lay a framework for looking at small-scale technology (Schumacher, 1973).

A small-scale view of technology is a necessary one in regards to appropriate technology. In essence, small-scale technologies are the core of appropriate technologies. From local irrigation to livestock hygiene to manual tool usage to solar panels to stone masonry to textiles, appropriate technology concerns itself in a major way with small-scale technologies (Darrow, 1986). With these different approaches to the idea of appropriate technology, it is easy to see that a direct definition and set of criteria for appropriate technologies does not exist. Rather, it is easier to understand what is inappropriate about certain technologies than to specify what is or should be appropriate (Teitel, 1993).

3.5.2 Fundamentals of Appropriate Technology

The concept of appropriate technology, also known as applied technology, embodies a modern holistic view of technology and the relationships between technology and society (McRobie, 1981). Unlike many other conceptual models, applied technology is concerned with the impact that technology has on many aspects of society and recognizes the vital role communities play in determining how any technology is used and how successful it is in fulfilling its purpose. In appropriate technology, emphasis is placed on making the technological solution easy to produce and maintain. Technological solutions develop in the context of societal structures giving attention to the effects on socioeconomic structures and the role of various members of the society. By taking the voice of the affected population into account, applied technology improves the long-term effects of that technology (McRobie, 1981; Darrow, 1986).

Applied technology recognizes the vital importance of the social consequences that occur when any technology is introduced to a society. When consideration is given to the people affected, the negative effects of the changes can be minimized and more importantly controlled (McRobie, 1981). By molding the solution to the culture, control remains within that culture. This eases maintenance, and improves the reception. It also multiplies the effectiveness of the action. In other words, applied technology seeks to ameliorate societal problems and minimize the effect of the solution itself (Darrow, 1986).

In order to understand a technological innovation to its fullest (its benefits, drawbacks, reasons for succeeding or failing), diffusion of that technology is necessary (Rogers, 1983). Diffusion is a form of communication with a specific audience, such as a regional population, articulated over a period of time. When a technology is diffused, it is slowly introduced, associated, and then induced into a particular social system (Rogers, 1983). If diffusion is incorporated in the development and introduction of an innovation, that technology's appropriateness becomes quite clear to that audience.

Darrow and Saxenian's Appropriate Technologies Sourcebook give numerous examples of feasible innovations and all have similar reasoning that underlies their appropriateness. First, they permit local needs to be more effectively met, because local people are involved in identifying and working to address these needs; for the same reasons, they are likely to be in harmony with local traditions and values. Second, these innovations mean the development of tools that extend human labor and skills, rather than machines that replace human labor and eliminate human skills. Finally, they represent a comprehensible and controllable scale of activities, organization and mistakes, at which people without management training can work together and understand what they are doing (Darrow, 1986).

It is important also, as stated earlier, to identify a technology's inappropriateness. Inappropriate technological innovations usually have some common problems. These problems can include needs and preferences of local markets and customers not taken into account adequately as well as technologies based on the use of imported materials rather than local ones (Teitel, 1993). Also, innovations are considered inappropriate if the technology has not been scaled down to fit the size of the local market or when skills are required that are not locally available or cannot be readily taught. Inappropriateness can also come from insufficient use of local labor, excessive use of capital goods or imports, or high costs (Teitel, 1993).

3.5.3 Present Status of Appropriate Technology

All of the concepts of appropriate technologies have been in play for nearly three decades and presently are seen in large organizations concerned with the incorporation of small-scale innovations. One such organization is the National Center for Appropriate Technology, one of the most prominent appropriate technology organizations in the United States.

This organization began with a foundation in Schumacher's ideas as the Intermediate Technology Development Group in London in the early 70's. It worked its way to the United States in the mid-seventies, as oil became a sparse commodity; hence, a need for more appropriate technologies for petroleum driven systems developed. The Community Services Administration then took hold of the organization and made it the National Center for Appropriate Technology in 1976. It grew as an organization until the Reagan administration, which brought about the end of the Community Services Administration and all government funding to the National Center for Appropriate Technology.

Since then it has reestablished itself and presently promotes appropriate technology development (especially in the areas of low socioeconomic status in this nation). During its re-growth in the late 80's an early 90's, the National Center for Appropriate Technology helped to produce two other prominent appropriate technology organizations: The National Appropriate Technology Assistance Service, which was a phone access, technical assistance service for people interested in energy conservation and renewable energy (ended in 1994); and the Appropriate Technology Transfer to Rural Areas program, which serves farmers, ranchers, Cooperative Extension agents, and others interested in reducing chemical inputs, conserving soils and water, and/or diversifying their agriculture operations (the bulk of the above information was taken from the NCAT web-page, 1998).

3.6 The Chesapeake Bay

Where fresh water from rivers combines with the salt water from the ocean a complex system known as an estuary is formed; the Chesapeake Bay is such a system. The Chesapeake Bay is the largest estuary in North America and the second largest in the world. It is 195 miles long and between 3 and 25 miles wide, and is surrounded by a shoreline 4400 miles long and reaches a depth of 153 feet, with an average depth of twenty one feet (Mariner, 1998).

The Chesapeake Bay is a massive ecosystem. It is home to some 2,700 species of wildlife including 200 species of fish. The Chesapeake Bay and its surrounding drainage basin combine to form a 64 thousand square mile watershed spanning six states – Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia. This watershed is home to a human population of 15 million and growing (CBF, 1998).

Years of unsound environmental practices have taken their toll on the once vibrant natural resource. Accounts by early explorers depict mounds of oysters so tall that they were navigational hazards. Papers from colonial times tell of fish catches of 22 million shad and 100 million herring. Currently oyster populations are less than 1 percent of what their levels were when settlers first came to this region. Years of human interaction have reduced the Chesapeake Bay to what it is today. Three thousand acres of wetlands in the Bay area disappear each year. The current amount of wetlands is at forty percent of the Chesapeake's original count, fifty percent of forest buffers have been lost and roughly only 65,000 acres or ten percent of the Bay's underwater aquatic grasses exist today from the estimated original number of 600,000 acres (CBF, 1998).

As a vacation spot the Chesapeake Bay draws many tourists each year. The Bay provides boating, fishing and camping among other activities for recreationalists. Industries in the Chesapeake Bay area include fishing and shipping. The commercial fishing industry provides much of the sea food we eat, and the shipping industry is a major staple for the local economy. Approximately 90 million tons of goods are exported and imported through the Baltimore and Hampton Roads ports each year (Mariner, 1998).

Baltimore Harbor itself is the location of many years of industrial activity, one major company that is currently operating there is Bethlehem Steel (Mountford, 1998). Up stream industries, such as large and small scale live stock and farming businesses, affect the bay as well. Long term industrial activity has left the harbor with many contaminated "hot spots". The Maryland state government in state statute 5-1101 and 5-1102 has designated a geographic line from Rock Point to North Point. Dredge material taken from behind this line toward the harbor must be dealt with in appropriate manner; open dumping bans and strict containment regulations are in effect.

3.6.1 Contaminants and Sediments

To simplify the analysis part of this report we need to define and briefly discuss the topic of contaminants, specifically contaminants in dredge spoils. For purposes of this report we are defining contaminants to be any metals, industrial chemicals and amounts of nutrients that are higher than normal levels. Formal definitions of these terms can be found in Appendix C, along with useful definitions of terms pertinent to ecological engineering and contaminated sediments in the Chesapeake Bay area.

Because our research has primarily been in the Baltimore Harbor area, our analyses of contaminants is limited to that region. Some of the prominent contaminants in this area are excessive amounts of zinc, copper, magnesium, these are mostly from industrial processes. Other contaminants include PCB's, PAH's, phosphorus, and nitrogen (NRC, 1998). In addition to industrial processes, these contaminants come from fertilizers, manure piles, and combustion engines. Major sources of nitrogen and phosphorus come from agriculture. Agriculture contributes one-third of the nitrogen and one-half of the phosphorus that enters the bay.

4.0 Methodology

The goal of this project was to assist the Bioengineering and Environmental Systems Division of the National Science Foundation by identifying and examining the links and mutual focus of specific fields of ecological engineering. We utilized the example of contaminated dredge spoils in the Chesapeake Bay as a case study to examine the common elements of these ecological engineering fields. This was done in order to recommend possible avenues that approach a sustainable development of these interrelated disciplines. Since this project was primarily research-based, our approach consisted largely of archival research of recent publications and personal interviews with various organizations related to these areas.

4.1 Literature review and research

In order to become more familiar with the concepts and topics of this project, pertinent literature was reviewed. The primary disciplines of ecological engineering – environmental engineering, environmental technology, industrial ecology, and appropriate technology – were examined. The sum of the literature review contains six main sections, four for the given topic areas, one regarding the encompassing field of ecological engineering, and one concerning the Chesapeake Bay.

Archival research was continually conducted throughout the project's development. For a thorough analysis, literature pertaining to ecological engineering practices, industrial practices, and environmental organizations in the Bay area was needed. This research was conducted at the Foundation, carefully scrutinized internet web sites, and in surrounding libraries and agencies – Georgetown University Library, Maryland Port Authority, Chesapeake Bay Foundation, U.S. Department of Interior, Institute for Local Self Reliance.

4.2 Identification of environmental problems and helpful organizations

Because the issue of contaminated sediment in the Chesapeake Bay is exemplary of the interconnectedness of the above disciplines of ecological engineering, environmental problems and companies, agencies, and organizations associated with those problems and their solutions were identified within the Baltimore area of the Bay. Upon researching the backgrounds and goals of these companies, agencies, and organizations, we used them as a resource for interviews. The process of identifying and locating desired organizations was accomplished, for the most part, through discussions and informal interviews with our liaisons at the National Science Foundation. These gentlemen identified a large number of organizations from which we found appropriate ones for our topics of study. Contact resources were not only our liaisons at the Foundation, but also included individuals we interviewed from companies, agencies, and organizations.

Criteria for choosing organizations or individuals to interview follows. First, the company, agency, or organization must have some level of involvement with contaminated sediment removal or disposal in the Baltimore area of the Chesapeake Bay. Second, an understanding of or authority in the technological, political, regional, and economic issues with regards to the Bay was needed. Finally, they must be able to benefit from a better understanding of the collaboration of ecological engineering disciplines.

4.3 Interviews

Interviews were conducted in order to gain insight into factual information regarding the Chesapeake Bay case study as well as opinions of those involved in environmental programs and projects. Questions were developed in order to have a basis by which we could conduct interviews. A list of those interviewed, their affiliations, order in which the interviews were conducted, and the questions asked can be found in Appendix B.

4.3.1 Interview development

Some of the information we needed from individuals was general, some highly specific. Because of this, three types of interviews were utilized: formal interviews, informal interviews, and secondary, or follow-up, interviews. Both general and specific questions that were in accordance with our final goals were developed for three interview types.

1. *Informal interviews*, or primary interviews, were used infrequently. Their purpose was to narrow, through discussion, a broad range of issues to be researched. Specific issues were addressed, but questions were open ended in order for all possible avenues to be addressed. These interviews were largely with individuals at the National Science Foundation. The discussion-type interviews were essential in developing a specific path for our research on ecological engineering.
2. *Formal interviews* were of a more traditional nature. Straight-forward questions about the individual's background, the organization's purposes, and current projects in fields related to ecological engineering and dredging in the Chesapeake Bay were

standard and uniform throughout all formal interviews. These interviews also gave us useful contact information.

3. *Secondary (follow-up) interviews* were of a formal style, but dealt with specific topics noted in earlier interviews. Since background and project information had already been attained from the individual(s), the secondary interview was used to pinpoint pertinent and essential issues of our research. The questions asked were developed specifically for each interviewee to address a particular topic of concern.

4.3.2 Initial interviews with representatives from chosen organizations

The interviews we conducted attempted to gain knowledge from the individuals on specific fields in which they had experience. Using the three types of interviews aforementioned, we gained insight into the four arenas of ecological engineering with regard to dredging in the Chesapeake Bay. Because certain Chesapeake Bay issues are sensitive and can be the cause of much disagreement, direct references to those interviewed were not made in our analysis; a list of interviewees can be found in Appendix B, section B.1. The useful information gathered here helped us identify the present and future concerns of ecological engineering disciplines.

4.3.3 Follow-up interviews

As our research progressed and new topics revealed themselves, it was apparent, on occasion, that more information was needed; therefore, we conducted secondary interviews – detailed above – with persons or organizations with which we had previously conversed. Because of the time constraints of our research, some of these discussions were over the telephone rather than in person. These follow-up interviews helped us focus questionable areas and tie loose ends from previous interviews or research.

4.4 Analysis of ecological engineering hindrances

Once all information was gathered from archival research and interviews, it was organized into the categories of terminology/technology, public opinion, and policy/economics. From these categories, hypotheses were developed to give a focussed analysis of Bay problems and hindrances in the collaboration of ecological engineering disciplines.

4.4.1 Chesapeake Bay Case Study

We discovered future research areas through the analysis of interviews, and archival research. Our project, using the example of contaminated sediment removal in the Baltimore area of the Chesapeake Bay, is an approach through which the National Science Foundation can learn the present status and possible future of ecological engineering topics. Because it is a major regional concern and has extensive involvement from numerous organizations, agencies, and companies, the Bay case study was an ideal example of ecological engineering interactions.

4.4.2 Future research and areas of concern

From our analyses, new efforts for sustainability of ecological practices became apparent. Therefore, this project recommends methods of developing stronger links between the environmental fields we studied so that they might aid each other in efficiency and progression, not only with regards to the Chesapeake Bay, but also in general. These recommendations come from conclusions made after analysis of ecological engineering disciplines' collaboration in the categories of terminology/technology, public opinion, and policy/economics.

4.5 Conclusions drawn on ecological engineering and the Bay

Through our research and interview analysis, and using the Chesapeake example, we have drawn conclusions on the present status and possible future of environmental engineering and technology, industrial ecology, and appropriate technology. Using the hypotheses regarding terminology, public opinion, and economics in our analysis, we concluded on hindrances to the progression and sustainability of ecological engineering. Our conclusions and resulting recommendations concerning those hindrances – education, cooperation, and mutual technological goals – once produced and written were then presented.

4.6 Presentation of findings

In this formal report, we presented, to the National Science Foundation, our results that suggest existing unity and make recommendations on important future concerns within environmental studies. Also, in our final week at the National Science Foundation, on December 15, 1998, we provided an oral and visual presentation. Those who attended included our project advisors from WPI, our liaisons from the National Science Foundation, and those individuals whom we interviewed. In order for our conclusions and recommendations to be heard and hopefully used by all those involved with our project, this final presentation was necessary.

Task Chart of Methods

The progression of the above procedures during our seven week time frame can be seen in the following chart.

# / week:	One	Two	Three	Four	Five	Six	Seven	Eight
4.1(done)								
4.2	■	■						
4.3.1	■	■						
4.3.2		■	■	■				
4.3.3			■	■	■			
4.4				■	■	■		
4.5				■	■	■	■	
4.6								■

5.0 Results and Analysis

5.1 Introduction

As a result of our research, we have defined ecological engineering to be an environmental arena that attempts to engineer, whether through method or technological device, ecologies (both micro and macro) using the four environmental disciplines, which we have previously discussed. Because we discovered that the terminology that defines these disciplines is more fluid than concrete, the term ecological engineering is loosely defined as well. Just as with appropriate technology, it is easier to say what ecological engineering is not rather than explain what it is outright (Mitsch 1989). For the purpose of this study, we found it easier to examine, by dividing this environmental arena into our four topic areas.

Thus far, the disciplines of environmental engineering, environmental technology, industrial ecology, and appropriate technology were discussed in a broad sense. We have attempted to define them in simplified terms as well as provide insight into their origins and current status. Aiming to explore in detail the interrelations of these four disciplines, the examination of a specific case study – which is the environmental factors and concerns regarding contaminated sediment removal in the Baltimore area of the Chesapeake Bay – has shown how they do and do not interact with one another. Our objective has been to discover ways in which these four environmental disciplines can collaborate more efficiently.

This next section will explore in more depth the concept of ecological engineering. To examine each of ecological engineering's four sub-categories in their entirety, hypotheses must be established in order to direct their analysis. A general hypothesis regarding ecological engineering and its future focus is as follows:

> All areas considered to be part of ecological engineering are molding together in a way that makes them interdependent. Unfortunately, due to three factors: technology / terminology, public opinion, and policy / economics, the progress to effective futures of these areas is possibly limited. It is the reformulation of the above three factors that will give sustainability to the interdependence of environmental disciplines.

From this, three more specific hypotheses are clear:

1) No matter how useful or beneficial certain technologies and methods in ecological engineering, progress toward applicable solutions in any of these disciplines is impossible without the support of local public opinion.
2) Current policies, especially those of economics, politics, and legislation, tend to be an encumbrance rather than a facilitator of the progress of environmental disciplines.
3) Variance in agreed definitions for specific terminology of the disciplines found within ecological engineering hinders the collaboration of these disciplines. As a result of lacking collaboration, the instigation of current and future technologies is confined to the limited ideologies of those technologies' respective fields.

The following analysis is based on the above hypotheses as well as parameters set in broadly defining ecological engineering and its disciplines. Using issues raised through the study of contaminated dredge material in the Baltimore area of the

Chesapeake Bay, this analysis will pinpoint developmental hindrances in environmental technology, industrial ecology, environmental engineering, and appropriate technology.

5.2 Public Opinion

Regarding the first issue in our analysis concerning the interdependence of ecological engineering fields, there is a hypothesis to be proven. In short: no matter how useful or beneficial certain technologies and methods in ecological engineering, progress toward applicable solutions in any of these disciplines is impossible without the support of local public opinion.

In order to show that public opinion plays a major role in the directions which technologies and engineering methods advance, it is necessary to define a useful meaning of public opinion. For the purpose of this analysis, public opinion, more specifically, local public opinion – that which is limited to a particular geographic region – includes all stated viewpoints and actions in which the general public plays a vital role. Public opinion also includes those expressions which are legal rights as well as those manifested in democratic principles and proceedings; this includes for the most part localized public meetings. The words "feelings" and "perceptions" will also be used in congruence with the term "public opinion."

Because all engineering methods and new technologies originate through individual's ideas and because individuals are influenced by their surrounding communities, the methods and technologies themselves are directly and indirectly influenced by public viewpoints and feelings. Also, because the environmental disciplines with which we concern ourselves – environmental engineering, environmental technology, industrial ecology, and appropriate technology – are still developing and are not yet as concrete as most other engineering and science disciplines, perceptions of needs and requirements for the environmental disciplines can be very diverse. It is the diversity, or incongruence rather, of these view points that causes difficulty in the progression of engineering methods and technologies for preserving the environment.

5.2.1 Public Opinion and Environmental Engineering

As stated earlier, environmental engineering deals, for the most part, with waste management and pollution cleanup. The way public opinion relates to this is simple; people do not want the waste that they produce. Since every one of us produces wastes that can possibly harm our local environment, problems of pollution of the environment are integral parts within the daily lives of all people in the United States. It is an unfortunate fact, however, that many people refuse to deal with the waste byproducts of their daily consumption.

Managing wastes is, therefore, something that can be aided by public opinion leading to public action. If an individual is conscious of the waste he or she produces, that individual will be able to understand the origins of wastes other than his or her own. Through that the public will come closer to having a viewpoint that helps environmental engineering in its efforts to manage wastes and clean pollution.

Regarding contaminated sediment removal in the Baltimore area of the Chesapeake Bay, perceptions of removed contaminated sediments are generally those of "dangerous contaminated wastes." Unfortunately, people do not associate that "waste" material with its possible origins in their every day lives. Fertilizing a lawn or farm, flushing toilet, washing cars, and many other daily activities all create contaminated wastewater that goes into the bay via its tributaries. For example, the Baltimore area of the bay is contaminated due to this and local industrial outflows. But no matter what the cause, the opinion remains that people do not want a "dirty" Bay.

With disdain toward a filthy Bay area as well as a refusal to take responsibility for personal and regional contaminants, there is a conflict of opinions regarding how that "waste" material, or pollution, should be managed. People want clean water, and assume – regarding sediments – that dredging can cause the water to be more polluted. The fact is, re-circulation of contaminants is not at all a major cause of Chesapeake Bay water pollution. In fact, we discovered from numerous interviews that only a small percentage of the contaminants in the sediment can be considered hazardous; the large part of the contamination in Bay-water sediment is excessive nutrient deposits. It can be seen that lack of information or communication can cause a public viewpoint that can be a hindrance toward certain environmental engineering techniques such as containing the dredge material rather than excessively processing it.

From our research in publications and numerous interviews we have discovered that, public viewpoints of environmental engineering are vague. Because the field itself is not concretely defined – unlike mechanical, electrical, and chemical engineering – variance of opinions are extensive. Individuals might have the same overall view, but, because of a semantic difference with regard to environmental engineering and its definition, conflict may be present.

5.2.2 Public Opinion and Environmental Technology

In efforts to clean present and prevent future pollution of the Bay, environmental technologies have been developed. The usefulness of those technologies, however scientifically sound, are limited by public opinion. An excellent example, concerning contaminated sediment and how public opinion has direct bearing on it is found below in an example about Hart-Miller Island.

The technology used for contaminated sediment disposal, in one, case is containment. Hart-Miller Island, a man made island in the Baltimore area of the Chesapeake Bay that acts as a permanent containment unit for dredged contaminated sediments, is a useful example of such technology. Since the contaminants in the bay floor are mostly nutrients, the containment of the sediment is a logical, feasible, sustainable, and clean solution. The public perceptions of Hart-Miller Island, unfortunately, are not always supportive. Although the technologies and engineering methods of the island are scientifically sound, it houses no "hazardous" materials. Local individuals, however, perceive this dredge containment unit as a dangerous site because of their own lack of education regarding its purposes. From this, we can see that certain technologies are good only if perceived to be good.

As a result of the misconceptions the public has about the dredge material disposal site, Hart-Miller Island pays very close attention to what the local public population has to say about the disposal site. Initially the local populace was strongly opposed to the idea of having a disposal site and fought the construction from the beginning. However, through holding public meetings where the public can voice concerns and frustrations the government was able to educate the public about the construction of the island and containment of the material. In the end the local residents relented and allowed the construction to go forth. To keep the support of the public during the operation of the disposal site, Maryland Environmental Service continues to hold public information sessions where people can still voice concerns that may arise.

For instance, recently, at one such session a gentleman brought up a concern of his about the large number of birds on the island. His concern was that because of all the birds, fecal coliform problems might develop from a high concentration of bird excrement. In response to this, a study is underway to determine this. To keep the disposal site in operation, the operators of Hart-Miller Island listen to what the public has to say and oblige them; this way they have been able to keep support for the island at present.

Contaminated sediment can be removed and dealt with using many technologies (containment, treatment, etc.) Some of the most useful methods are unclear to local population, causing distrust and lack of positive support. Lack of understanding also hinders attempts to prevent contaminants from entering the bay. People only see dirty water, they do not understand the source of the filth; therefore, they only want the contaminants dealt with at the end of pipe and prevention is not even considered.

This puts a large barrier on those who deal with environmental technology, which has a basis in pollution prevention. If the public is unaware or refuses to be aware of the origins of pollution, those that deal with reevaluating and redeveloping those locations to be nonpolluting sources are at a loss. For example, a major pollutant in sediments and in the water of the Chesapeake Bay is excessive nutrients. These nutrients have origins in farm fertilizers and bio-solids as well as local treated and untreated wastewater. A technology which can be used to prevent pollution from these sources includes runoff prevention systems – improved irrigation systems, increased tree-cover, improved road routing and engineering, improved wastewater treatment techniques and plumbing improvement. Unfortunately, a gap in communication between those developing prevention techniques and technologies and the local public causes a lack or misunderstanding of those improvements and from that a barrier to their implementation.

Complex systems require greater research, are more difficult to describe to the population, and are more difficult to combine with other systems. In the case of environmental engineering, the effects of the complexity can be seen by the number of problems and how they interact. Fertilizer application methods in agriculture, lawn maintenance practices, forested areas near rivers, and dams are issues themselves but they all effect sediment removal. Like other environmental problems, the problem of sediment removal in the Chesapeake Bay requires efforts by many people in numerous ways. For this reason, researchers need to develop methods to deal with each aspect. One source of high amounts of nutrients comes from chicken farms near the rivers that flow into the Chesapeake Bay. Run-off from the chicken manure creates high concentrations of nutrients flowing into the Chesapeake's feeder streams and rivers. A way to help curb the flow of nutrients into the bay would be to convince farmers to plant more vegetation around their property so as to absorb some of the run-off from the manure piles. However, farmers must first be convinced of the benefits of changing their ways.

5.2.3 Public Opinion and Industrial Ecology

Unlike many European countries, in the United States, industries can avoid the responsibility of their wastes by passing them to consumers. Packaging material, disposable merchandise, and excessive advertising propaganda (junk mail) are just a few examples of this. In some European countries industries have to take responsibility for some of the post consumer wastes that occur when consumers are done with the product.

One example is BMW, once any BMW vehicle has been scrapped BMW is responsible for the appropriate disposal of the vehicle. With regards to the Baltimore area of the Chesapeake bay and sediment removal there, large regional industries, which produce products that contain contaminates such as nutrients or heavy metals, and sell those products to local consumers should be a major concern. Farmers will use the best fertilizer, for example, available for a good price. The industries that make that fertilizer can produce non-contaminating fertilizers, but do not. Since the consumer is uninformed about the effects of fertilizers that can cause water-body contamination, industries withhold from promoting environmental engineering and technology in their products. Industries should be held responsible in that there exists technologies to develop fertilizers that have concentrations of nutrients that are more readily absorbed by plants. The consumer is also responsible for contaminants from fertilizer. Due to old habits of farming handed down from generation to generation, some farmers still believe that more fertilizer is better so they typically are adding more fertilizer than is needed instead of using alternative methods such as split application of fertilizers. Split application is the addition of a calculated amount that the plants need right when they are planted then a secondary application when the plants are at their peak for fertilizer again. Thus the consumer, the farmer, is left to deal with the problem of how to properly apply the fertilizer.

The question of responsibility arises here. Should the consumer be more informed and force industries to produce environmentally friendly products through a profit motive, or should the industries be forced to produce safer products through legislation and policies? Is the consumer at fault for being uninformed? Is the industry at fault for wanting to make money with the least amount of expensive change to their business?

Since industrial ecology is a cycle that is concerned with more than simply the single association of producer and consumer, two more questions arise. With the promotion, from any source – public opinion, economics, policy, or technology – of environmentally friendly products, will industries be able to grow off of one another by using each others outputs? In addition, will an awareness of these "green" technologies, products, and methods be promoted by industries in order to change possible negative public viewpoints?

5.2.4 Public Opinion and Appropriate Technology

Nothing, which directly involves people, is self-sustainable. Whether or not people understand that every action of theirs has an impact on the environment, the fact remains that every action does have an impact because people are an integral part of their environments. Similarly, the reverse effect on the environment (its cleaning) cannot happen without the conscious aide of the resident individuals.

If containing contaminated sediments in a man made island (Hart-Miller, for example) is the best possible technology to dispose of them, then that is the appropriate technology. Contaminated sediments that are dredged have origins from individuals and industries that are an integral part of the bay area. For an appropriate technology to be used, it must be understood and accepted by all those on which it can have an effect. For this solution to the disposal of contaminated sediments, there is a major set back. Public opinions originate from many ideas and presumptions made about this appropriate technology are intertwined in those ideas. If this viewpoint is against the technology attempting to be incorporated, it will take a great deal of effort in education and public relations to be able to make the technology accepted.

Once again, it is seen that good, effective technologies and other innovations can be hindered or even rejected if the public views them as no good. The Hart-Miller Island example in section 5.2.2 demonstrates this clearly. A more general example of this is the blower vs. rake argument. The average size of an American residential yard is relatively small and the weight of leaves during Autumn on that lawn is also low and can be easily raked in a relatively short amount of time. Unfortunately, individuals across the nation insist on purchasing leaf blowers or paying for a lawn service that uses such equipment. Leaf blowers, in their manufacture, cause water and air pollution in the form of toxins, heavy metals, and other contaminants. In their use, noise pollution and air pollution are extremely prevalent. Rakes, on the other hand, have low amounts of manufacturing wastes, do not cause any air or noise pollution, they also aid physical well being, and actually gather leaves to be disposed of rather than further dispersing them. Clearly a rake is the appropriate technology, but due to many hundreds of personal, economic, commercial, and education factors, public opinion pushes toward the inappropriate technology of a leaf blower. This is not to say that blowers are entirely unnecessary, but in a general case across the country, a rake is more appropriate.

As far as the discipline of appropriate technology is concerned, with regards to ecological engineering, public opinion can vary. In most cases, viewpoints of local individuals are hindrances because of lack of knowledge on the subject of the environment. Education, responsibility, and general appeal of ecological and environmental subjects are among key elements in the future direction and focus of ecological engineering.

5.3 Policy

Social economic and political policy can act to encumber rather than facilitate environmental development and ecological collaboration. This encumbrance is the result of several factors specifically complexity, visibility and incompatibility. The scope and complexity of the environmental system requires significant investigation and attention. Environmental management's incompatibility with the existing social economic and political structure leads to difficulties in supporting environmental research and implementing the improvements dictated by that research. Support for environmental endeavors is further hindered by the lack of visibility of the scope and severity of the problem. Successful integration of environmental values with entrenched social, economic, and political structure is essential if disaster is to be averted, but there are many barriers to successful integration.

5.3.1 Complexity

Environmental systems are complex dynamic systems whose complexity arises from their sheer scale, diversity, and vast system of interdependent relationships. Progress in environmental endeavors requires acknowledgement of the complexity of the system involved. People accept that the environment is a complex system but they do not realize how complex it is. An example of how complex environmental systems is the analysis of contaminants in Baltimore Harbor. It is relatively easy to find contaminants in the area but it is not easy to figure where they are coming from and how to curb their flow into the harbor. The reason for this is that the contaminants may have been there for a substantial number of years. Many of the contaminants do not break down very fast; an example of this is DDT. There are still parent molecules, the originals, of this pesticide present in sediments in the Chesapeake Bay and that chemical has not been in use for decades. As a result of the slow decomposition, it is difficult to determine if high contamination levels are due to current unacceptable effluent flows or past build up because of previous ignorance and neglect. This presents a problem in developing acceptable levels of contaminants to be dumped into the harbor. Several attributes of the environmental system lead to this complexity.

Another factor adding to the complex nature of environmental systems is often vast systems covering miles and encompassing large regions. The Chesapeake Bay watershed spans approximately 64,000 square miles. This area encompasses both land and water including mountains, rivers and coastal plains. It encompasses sections of six states – Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia. The Chesapeake Bay is the largest estuary in North America and the second largest in the world.

Environmental systems are not only large they are also diverse. The Chesapeake Bay watershed is an excellent example of the diversity involved. Roughly two hundred species of fish and two thousand seven hundred plant species share the bay with an increasing human population currently numbering 15 million. Historically, the abundance and vitality of the watershed were legendary. A system with so many components requires consideration of numerous variables and therefore makes problem resolution more difficult.

Diversity and scale reveal the true complexity of the underlying system of intertwined relationships. Life cycles are common knowledge. Little fish eat algae, bigger fish eat the little fish, the big fish die, and decomposers convert dead fish into nutrients, new algae then consumes the new nutrients. Most people are aware of the existence of these interdependencies but they are unaware of the extent and complexity of these relationships. The interdependence also encompasses the human aspect as well. Dredging in the bay must be done to keep channels clear for big ships to come into and out of ports. These ships have a large impact on the area economy. Yet, when the dredging occurs the disturbance of the sediment can have an impact on local fish and shellfish populations, which can impact the fishing industry. Farmers impact both of these things by having topsoil run off from their farms and end up as the sediment in the bay. This erosion can be linked back to Thomas Jefferson's plow design.

By the sixteen hundreds, agriculture was well developed in the land around the Chesapeake Bay, but the damage was minimal since land had been cleared in small plots and allowed to grow back. Thomas Jefferson developed a new type of plow that was more efficient in the way it cut the ground. The plow blades overturned the soil much more easily than previous designs. But as a result of this the roots from the plants in the ground were turned to the surface and left to die. Without roots to hold the topsoil down it quickly began to erode. It was not until recently this century that new methods of planting are beginning to take hold that help prevent this. The result of this seemingly minor change was that large plots of land were cleared for agriculture and that the topsoil from these lands was loosened to the point that some farms lost all of their topsoil within twenty-five years. This topsoil found its way into the bay filling in large sections of land.

As a result of this increased erosion, mooring posts – used to secure boats – can now be found far inland.

5.3.2 Visibility

In gaining support for policy changes to be made, there needs to be an easy set of goals that can be presented simply. This way complex aspects will not confuse those who make the policy, this is where visibility becomes important. Problems with the environment, short of natural disasters, are not always an easy topic to define let alone explain in a way that is easy to understand. Gradual change and cost benefit determination act as obstacles that hinder the visibility of environmental issues. Because changes in the environment tend to occur at a gradual or slow rate an opponent to environmentally friendly policy can easily say that it appears, because so little is changing now that it is alright to put off decisions on those issues until later. It is also very hard to place a value on the environment in terms of a cost or dollar figure that is tangible to the untrained professional.

As a result in the tendency for environmental problems to occur on a gradually changing basis over long periods of time it is difficult in this day and age where things are viewed in short term to sometimes display these problems. Policy makers typically are looking at things in terms of short periods of time. But because of this they may not be willing or able to comprehend a long-term change. When viewed on a short-term scale it may appear to have hardly changed at all. A good example of this is septic tanks. Septic tanks around the Chesapeake Bay may have been in the ground for long periods of time. The nutrients that leach out of their septic fields move at extremely slow speeds through the ground. Now for argument sake, pretend that a septic tank is in the ground for twenty-five years. For all of those years nutrients have been moving through the soil towards the bay. At the end of twenty-five years the tank is removed. It would appear that the nutrient problem is taken care of. But, the nutrients that leached out are still in the ground and are now just getting to the bay. For the next twenty-five years those nutrients will be spilling into the bay. The septic tank is gone but the nutrients still present a problem. This type of slow gradual change makes it difficult to show how on a short-term basis the environment has been affected.

Comparing cost and benefits is a cornerstone of decision making, especially social, economic and political decision making. Unfortunately, the environmental system is more difficult to analyze with cost benefit analysis than many more traditional concerns. The reason for this is that the benefits of environmental factors are difficult to quantify. This is further complicated by the sheer size of the system. Cost is generally quantifiable in economic term, more accurately it is as quantifiable as more traditional economic factors. Lack of clear value tends to marginalize environmental concerns.

Setting an economic value for a cleaner Chesapeake Bay is virtually impossible because of the complexity issue discussed in section 5.3.1. Therefore, environmental needs are often passed over in favor of needs with more obvious economic values. This clearly hinders prevention approaches. Environmental engineering receives funding more easily because it is the approach used when disasters occur. Disasters catch people's attention and the value of clean up is clear even if it is not quantifiable. Since people feel the impact they are willing to invest in current and future work in the area. Pollution prevention has less apparent repercussions and therefore is more difficult to describe in terms of value. Like pollution prevention industrial ecology acts on the causes of the disaster and therefore faces similar problems. Causes of disasters are difficult to value, whereas repairing the effects of a disaster are far more visible and therefore have greater tangibility of value.

5.3.3 Incompatibility

All of the above factors combine with several others to produce numerous incompatibilities between the facets of ecological engineering. Human activities include research and implementation of environmental practices, which are more environmentally friendly. Environmental practices must be merged with those practices and perceptions, which form the foundation of society. Currently causing the incompatibility between the ecological engineering facets are accountability and societal mindsets.

Another problem with having numerous sources is that accountability is difficult if not impossible to determine. Decades ago, Bethlehem Steel Co. contaminated the Chesapeake Bay with large amounts of zinc and now take the accountability of that action and are utilizing new manufacturing techniques that reduce amounts of industrial waste. Unfortunately, smaller contributors, who may have played just as a significant a role when combined, are more difficult to blame since they did not act on the same scale. Large industries may be responsible for contamination but that does not make the other contributors free of blame and free of the responsibility to repair the damage caused by their role in the matter.

It is very difficult to determine what role each party had in the contamination of the bay. Although it is possible to determine, or at least approximate, the quantity of a specific substance, it is difficult to specify how much of the contaminant arrived from each source. Although the existing toxins may have some detrimental affect, it is the combination of several sources of toxins that poses a problem. This is further complicated by the lack of a benchmark, a known natural or uncontaminated level to be used as a baseline. Since all effluent contains some amount of nutrients and other chemicals, it is difficult to determine what concentration is too high.

When dealing with an already contaminated watershed, the issue is further complicated. Even if levels of a specific substance would normally be considered acceptable, the levels might change if the watershed is contaminated. Zinc contamination in the Chesapeake Bay may mean that acceptable levels for zinc should be lower than "natural". Parties that acted responsibly may be forced to pay for the irresponsibility of others. The irregularity of what "natural" is , still being insufficient, further complicates the matter of accountability.

Accountability is even more complex in cases of non-point sources. Agriculture is suspected of being one of the greatest sources of nutrient contamination, but the vital role of agriculture is difficult to argue with. Fertilizer, meant to improve food production, can be devastating when it reaches a watershed such as the Chesapeake Bay. Recent advances have allowed for decreased use of fertilizer. This may begin to solve the problem but it is not a complete solution.

Accountability is of more concern in prevention than treatment and is therefore more relevant to environmental engineering and industrial ecology. Accountability includes within it the source of the problem. When treating an affected area, the source is valuable in that it may give insight into the composition and characteristics of the contaminant. On the other hand, accountability of specific sources of contaminants is critical to developing a strategy to minimize pollution. Accountability in environmental concerns requires significant resolve but it is essential in the long-term.

Accepted social norms also pose problems. Lawns are notorious for their fertilizer runoff yet it is unlikely that people will easily cut back on fertilizer use and accept lawns that are not as green. Another social norm that hinders environmental maintenance, is the appreciation of an unobstructed view of the river. Forested areas on the river's edge play a vital role in the maintenance of a river, by absorbing runoff before it goes into the Chesapeake.

The current commercial structure has numerous adherents seeking to maintain the self-serving interests. Many of the powerful organizations can easily mobilize to put significant economic and political pressures in order to protect their interests. Environmental organizations are growing in strength and they now have considerable voice but their agenda needs far greater support. Influence takes time to develop but time will only make the demands greater. This is why minor changes in advance can prevent catastrophes and save lives. Greater concern for industrial pollution three decades ago, for instance, would have prevented many of our current problems. Such vision requires a long-term view and a long-term investment, since economic situations may change rapidly, but environmental changes are often slow and can take hundreds of years before restoration has reached significant landmarks.

5.4 Terminology and Technology

Since this report deals with finding ways that will help the disciplines within ecological engineering collaborate better, the following sections will deal with examining hindrances found within the areas of terminology and technology. Collaboration between terminology and technology has three main areas of hindrances. The first hindrance for the collaboration between terminology and technology comes from non-consistent definitions of terminology. The second area that exists between the two is, that terminology can directly influence technology. This influence can act as either a benefit or a hindrance. Instead of being a positive influence on technology, which would encourage it to flourish, terminology currently is behaving as a negative influence and causing hindrance of technology progression. Other hindrances do not come from the influence found on one another but instead come from a different source, this source stems from lack of support and funding. This lack of support and funding primarily affects technology.

5.4.1 Origins of Terminology Hindrances

As said above, the first problem area for the collaboration between terminology and technology comes mainly from lack of formal definitions. In other words, when multiple groups who have one ultimate goal in common or have direct bearing on each other, use the same words but have different definitions for them, little or nothing can get accomplished. This concept is similar to the idea of having the correct tool for the job, instead of performing poorly using the wrong tool. In the case of ecological engineering there may be several agencies or companies that have direct influence on a particular ecosystem. As an example, companies may be producing a product with byproducts that damage or destroy the ecology, such as the steel industry in Baltimore harbor. In this same case, the agencies may consist of numerous environmental groups who wish to preserve and save the ecology. A stumbling block toward the cooperation of these two bodies of people, toward cleaning up the ecology, could be lack of mutual definitions of certain terminology. An example of an inconcise term is sustainability. In an environmental sense sustainability typically follows a definition implying that when any method is to be used for a long period of time, whether it be an industrial process or restoration of a damaged environmental ecology, the environment must also be able to maintain a healthy and permanent state. For the industry, if the environmentally directed groups start talking about sustainability in context of an environmental problem that they are creating, confusion may arise due to a misunderstanding of terms. In industry sustainability may have a different but also correct definition. The industry's definition may be the prolongment of one of their industrial products or processes, or possibly even the company's sustainability by increased yearly growth. The industry may not realize what it is exactly that the environmental groups are asking for and just assume they want an immediate fix of the problem which may only be a short term one versus the desired long term or permanent fix.

In the case of the Chesapeake Bay, concerning contaminated sediment, there are discrepancies in the definition of contamination. "Contaminated" is deemed to be foreign or excessive amounts of chemicals not naturally occurring in the Chesapeake Bay. For some environmental organizations this includes industrial chemicals and excessive amounts of nutrients. Other groups however view contaminated without the inclusion of excessive nutrients. The government has designated a geographic location around Baltimore harbor to be legally contaminated regardless of whether all of it is or not (see section 3.6). The thought behind this is to keep speculation out of classifying what is contaminated and what is not. Much of the dredge material taken out of the Baltimore Harbor area is taken to the Hart-Miller Island disposal site.

Based upon the government's definition of contaminated, Hart-Miller island is receiving contaminated sediment. But, when we had the privilege of taking a tour of Hart-Miller Island disposal site the gentleman who conducted our tour said that for many years Hart-Miller had not received contaminated material. This presents somewhat of a contradiction, are they receiving contaminated sediment or not? We have concluded that what has happened is that two different parties are using two different definitions for the same term. As can be seen this presents a problem. Without a clear definition for sediment, Hart-Miller Island could possibly be filling up with relatively harmless sediment instead of taking harmful contaminated sediment, which it is designed for. This would be a waste of precious space, which is quickly disappearing from the disposal site.

Another issue concerning the Hart-Miller Island disposal site is that it does not include excessive nutrients in its definition. A result of this is the possible redistribution of large quantities of nutrients being dumped back into the bay when they off load water from the sediment as it is pumped into the holding cell.

5.4.2 Terminology's Effects on Technology

The lack of precise definitions effects technology primarily in two ways. The first way being that if different arenas of technology may be developing technology that can directly benefit another but if the two areas communicating with a common terminology then it is quite possible that the technology exchange will not occur. The second area affected by lack of clear definition is when two different parties of people have different definitions. For example what a preservationist considers clean material being dumped into an estuary may be different than the company dumping it considers to be clean. The material may be clean by government standards but as far as the preservationist is concerned it is still dirty. As a result of this difference in definition possible technology that might be used to make the material cleaner is not used.

5.4.3 Dredging the Chesapeake

Having already talked about how terminology and technology can affect each other in the general sense. It is apropos to talk about them with regards to dredging contaminated material in the Chesapeake Bay since that is the case study for this project. The first example deals with the definition of contaminants. For our project we have defined contaminants as: any metals, industrial chemicals and amounts of nutrients that are higher than normal levels ordinarily found in sediment on the bottom of the Chesapeake Bay. On the other hand, according to the perspective of the people we interviewed, "contaminated" may take different meanings. When we took a tour of Hart-Miller Island, which is a dredge spoil disposal site, contaminated meant that the sediment was laced with industrial wastes of some sort, but not necessarily excessive nutrients. However, individuals involved with contaminant source analysis as well as treatment stated that "contaminated" does indeed include excessive contaminants. Thus, this is a relatively large obstacle. If industries or dredge disposal sites do not include nutrients as part of their definition for contamination then they may not be taking this into consideration when treating their effluent. Likewise, if environmental organizations are considering nutrients as part of their definition then they may not be communicating properly with industry in trying to help them treat their waste.

With this lack of clear definition for contamination comes the hindrance of technology. Because the government mandates what "clean" is an industry must only bring their effluents up to that specification. In the case of the Hart-Miller Island dredge material disposal site, they only need be within what the government has mandated, this may not necessarily include consideration for nutrients. Now, this may for all intents and purposes be sufficiently clean enough for the surrounding environment to survive. However, without a clear and concise definition of what "clean" is, in both the government's eyes and environmental agency's, then what is the best way to determine how clean the effluent really needs to be? As far as people on Hart-Miller Island can see the area around the island is clean, but coming from other sources some people suspect that the disposal site is one of the largest sources of nutrients being dumped back into the bay. Perhaps the ecology around the island is flourishing because the harmful nutrients are being swept down stream by underwater currents and causing damage elsewhere. As a possible result of this, the government does not require more stringent secondary effluent treatment technologies. Without government pressure to use secondary treatment methods those technologies that could be developed for this purpose are not developed. Or perhaps current technologies that do exist and have no backing because of lack of support are not utilized. Issues of support are closely linked to issues with public opinion and policies / economics; they have been discussed in sections 5.2 and 5.3.

5.4.4 Possible Futures

As discussed in the introduction of this report the goal of this project is to discover ways in which the facets within ecological engineering can be made to collaborate together better. This will be achieved by examining the case study of dredging contaminated sediments in the Chesapeake Bay. Before we can begin on how they can be made to work better it is best if we discuss first an ideal collaboration and functioning of these areas.

5.4.4.1 Relations of Environmental Technology and Engineering

The best place to begin with is discussing the natures and relationships between environmental engineering and environmental technology. Strictly speaking, the respective definitions for these two terms can be interpreted in a variety of ways. The first definitions that apply are concise ones similar to those in an encyclopedia: environmental engineering means the process of designing and constructing environmentally sound and friendly technologies; environmental technology is the process of applying environmentally friendly technology. Definitions for these areas found within the environmental arena typically mean something different, as we learned from informal interviews with individuals at the National Science Foundation. For example, environmental technology is the field of work that encompasses pollution prevention. It looks at ways in which pollution may be avoided either by application of new technologies or altering processes. A good example of environmental engineering is developing new aerosol chemicals that do not hurt the ozone. Environmental engineering is the field of work and research that deals with an end of pipe area. Meaning that environmental engineering focuses primarily on pollution control or examines processes or technology that assists in pollution clean up. An example of environmental engineering is bio-remediation in the Exxon Valdez oil spill in Alaska. In this case, proposals were made to apply certain chemicals to the area that would stimulate local bacteria to grow that would process the hydrocarbons in the oil.

In an ideal setting, environmental engineering and environmental technology would collaborate in everything they do because they can affect each other so easily. Currently environmental engineering and environmental technology do collaborate to some extent, but not to the extent that they should be. For environmental engineering to be effective at some point it will have to look up stream or up the pipe from which the pollution is coming from even if environmental technology develops ways that are so efficient that pollution never affects the environment because it is treated so fast. Environmental engineering is not supposed to be a permanent fixture, it is needs to be able to stop when things are clean again, it is not cost beneficial to continuously keep in motion clean up technologies when the source of the pollution can be curbed. So in the interest in being efficient, environmental engineering will look up stream to see where it might be able to stop some of the flow of the pollution.

This might take place by adding or replacing old technology with new technology or even just altering the timing of a process. New methods such as altering the timing of a process can produce a huge difference. For instance, if an industrial plant needs to flush certain chemical tanks before proceeding with a process, having all the tanks dumping at the same time might overwhelm waste treatment processes. But if the tanks are dumped separately at spaced time intervals then the waste treatment will have more time to deal with smaller amounts of chemicals. This is a good example of environmental engineering stepping over its boundaries into the realm of environmental technology. Environmental engineering stepping out of its normal boundary is not entirely environmental engineering because it does not deal with just pollution prevention but it is now mixing the pollution prevention with pollution control.

The process of crossing over boundaries works the other way as well. Environmental technology can step into the realm of environmental engineering. This is demonstrated in the process of preventing pollution, when environmental technology runs into environmental engineering as it comes up stream to examine the source of the pollution. Here they cross paths and begin to cooperate. Environmental engineering and environmental technology both work toward the same end, sometimes separately but they also can be combined into one entity.

5.4.4.2 Appropriate Technology, Environmental Technology and Engineering

Appropriate technology deals with the idea of sustainability of a solution to a problem. The concept of sustainability means that it takes into consideration all aspects including economic, geographic, locally available resources, so that the end result can be hopefully maintained for a long period of time if not indefinitely. Typically, the ideas of appropriate technology and sustainability are considered interchangeable with each other.

The concept of appropriate technology deals with applying the most appropriate solution to a given situation taking into account many factors, some of which are stated above. An excellent example of the application of appropriate technology principles is the use of marsh, or wetland, for secondary water treatment. Instead of dumping the effluent from a wastewater treatment plant directly into the Chesapeake Bay, which would add more nutrients, one of the ideas is to add secondary water treatment facilities after the initial treatment plants.

This secondary water treatment can be achieved in a number of different ways. With enough money an actual plant can be constructed and maintained, costing millions of dollars in initial construction and up keep. An alternative method has been developed by numerous organizations including the Environmental Protection Agency, that would incorporate wetlands to treat wastewater. The effluent would flow through the marsh, filtering out nutrients by absorption, before the water went into the bay. This exemplifies appropriate technology.

Instead of automatically choosing the high-end expensive technology, alternative methods that are cheaper and just as effective are being considered. A wetland would be cheaper in the long run because it is self-sustaining and can be constructed out of dredge material, which could lend itself to dealing with a portion of the dredge material instead of dumping it.

Appropriate technology fits into the picture of environmental engineering and environmental technology with the concept of achieving sustainability through the use of the most appropriate technology for the environment. In the case of environmental engineering, when a restoration project is underway, which technologies to use must be decided. If there is a limiting constraint of a small budget, which there often is, a technology that can get the most for the money invested and hopefully be a long term sustainable solution should be chosen. Using a marsh or wetland as a secondary treatment for wastewater is a good example of this. Obviously, wastewater should not be dumped straight into the environment so a solution, as discussed above, is to use a marsh or wetland to absorb some of the contaminants out of the wastewater. This provides a solution, which is relatively inexpensive and able to operate on a prolonged basis.

When being applied in conjunction with environmental technology, appropriate technology comes into play of choosing long-term technologies that lend themselves to the prolongment of the environment. The prolongment of the environment specifically is affected by how pollution is prevented from occurring. Similar to the concept of how environmental engineering and environmental technology overlap, the role of appropriate technology is one that ensures that the best and most appropriate technologies and processes are used in its endeavor.

5.4.4.3 The Role of Industrial Ecology

Industrial ecology is the concept of a closed industrial system, where a closed loop is developed between industries. Where the byproducts of one industry would go to another industry and become its raw material and in this fashion continue until all waste is virtually eliminated because there always exists an industrial need for the waste material. This concept can be applied to other areas other than just a strict industrial sense. Industrial ecology is the arena that ideally encompasses all the aspects and collaborations of the disciplines environmental engineering, environmental technology and appropriate technology.

Environmental engineering is incorporated into industrial ecology in that to design industries to collaborate with each other a life cycle analysis must be done first. In other words, the processes within the industry, the life cycle, must be examined. Part of that examination is observing the pollution that comes out of the industry. Environmental engineering comes into play by addressing how to deal with pollution. One of the solutions in environmental engineering might be to turn the effluent into something else usable by another industry through the addition of certain chemicals.

Environmental technology exists within the confines of ecological engineering in that the life cycle assessment of the industry will incorporate examination of processes used within it. Environmental technology comes into play by helping to devise ways that might be used to prevent, reduce, or change ahead of time possible effluents from processes that automatically can be shipped off to be used into another industry that can benefit from them. Thus, saving time and preventing having to change the effluent at the end with environmental engineering techniques.

Appropriate technology is incorporated into industrial ecology in that an ecological cycle of industries requires specific technologies appropriate to their own parts of the cycle. Because appropriate technology is an integral part in the relationship between environmental engineering and environmental technology it is directly related to the function of industrial ecology. The idea behind industrial ecology is to develop sustainable industrial relationships through the use of environmental engineering and environmental technology.

In short in an ideal situation, not only would the environment benefit, but these disciplines would benefit greatly from collaborating with each other. This section provides a sample way that they could best work together. However, in reality these areas are not to this level yet especially in the case of the Chesapeake Bay.

5.4.5 Current States of the Ecological Disciplines in Chesapeake Bay

What we have found about dredging contaminated materials in the Chesapeake Bay, in relation to the disciplines discussed here, is that there is little cooperation among them. Pointed out before, environmental engineering and environmental technology cooperate with each other somewhat, simply because they really don't exist without the other. But, there appears not to be any push toward any type of development of an industrial ecology. As far as appropriate technology, it is for the most part only applied to a limited extent.

When it comes to environmental engineering with relation to contaminated dredge materials very little is being done with the actual treatment of pollutants. What is being done in this area deals primarily with where to put this material, this is where places like Hart-Miller Island dredge disposal sites come into play. To alleviate confusion regarding from what and where contaminated dredge material comes, the government generally mandates a certain geographic location, regardless of specific sediment contents, will be considered contaminated and must be handled and disposed of accordingly. As discussed before, for purposes of this report, we are considering nutrients to be a type of contaminant. What is being done currently in this environmental field is testing of specific field sites to determine composition and quantity of contaminants in these areas, on order to develop treatment methods. However, these field tests are usually dealing with toxic substances and not excessive nutrients.

As far as environmental technology, some progression is being made with respect to contaminated dredge material. Because of legislation, namely the Clean Water Act, industries have been forced to reduce the amounts of pollutants that they can legally dump. Newer technologies have also been implemented in industrial processes that allow in the reduction of chemicals being dumped. An example is the Bethlehem steel mill in the Baltimore harbor. This steel mill has been helping to experiment in the process of dissolving slake, the oxidized by-product that is scrapped off of steel when it has cooled from a molten state, in acid. The dissolved slake is then injected into sludge to be treated by wastewater treatment plants.

Appropriate technology has not yet been realized to its full concept in relation to contaminated dredge materials in the Chesapeake Bay. Currently dealing with contaminated materials is done on a reactionary basis. Reactionary in this context means nothing is done until after the fact. For instance instead of preventing a spill of contaminants people wait to clean it up and suffer the intermediate consequences. The mere idea of dealing in a reactionary method is contradictory to the concept of sustainability found within appropriate technology. Essentially dredge material taken off of the bottom of the bay is classified and then transported to a respective disposal site. There are no long-term sustainable plans on how to deal with contaminated dredge material or for that matter dredge material in general, clean or contaminated.

The application of industrial ecology in the bay is virtually non-existent. Noting the lack of collaboration of the other disciplines, there also has not been any big pushes for a sustainable solution that would incorporate a circular life cycle of contaminated dredge material or clean dredge material for that matter. As said before dealing with the general area of dredge material, is handled on a reactionary basis. Only when there is no longer room for the dredge material or disposal sites are rapidly running out storage space for the material, is any attention paid to finding new places or new ways of disposing of the material. No long-term solution has even been proposed as to what can be done on a sustainable basis or proper management of dredge material. A few of solutions that are being used to handle the material are wetland reconstruction and possible injection into sludge for treatment into fertilizer. As good as these solutions sound they are not yet long-term solutions.

Although all areas we consider to be apart of ecological engineering are progressing toward interdependence the above factors of technology/terminology, policy/economics, and public opinion limit the progress of effective futures. A reformulation of these hindrances may be possible through the development of mutual understanding and communication among these interdependent disciplines.

6.0 Conclusions

From the three points of analysis in chapter four – terminology / technology, policy, and public opinion – it can be seen that collaboration exists among fields within ecological engineering on a technological and analytical level. That is, the disciplines of ecological engineering – environmental technology, environmental engineering, appropriate technology, and industrial ecology – are united through their individual actions and purposes. Unfortunately, there exists a lack of mutual understanding of these connections, which is a severe hindrance. This knowledge barrier prevents the development and sustainability of a mutually agreeable future among ecological engineering disciplines. The creation of this barrier comes directly from lack of concise definitions of purposes and technological approaches, funding, and public support.

6.1 Regarding Terminology and Technology

In chapter four, we examined the current states of terminology and technology in relation to the Chesapeake Bay and addressed how environmental engineering, environmental technology, appropriate technology, and industrial ecology could cooperate with concise terminology and shared technologies. Because there is no set of agreed upon terms concerning environmental disciplines, efficient collaboration of the facets of ecological engineering is minimal. Incongruent definitions of terms as broad as "environmental engineering" and "appropriate technology" as well as ones as precise as "contaminated" and "clean" can make communication among related disciplines ineffective. In this project's research, we have repeatedly found different definitions for and opinions of popular terminology. For example, in one interview, an individual said that it was good to have loosely defined terms to allow for many interpretations. This idea may work for brainstorming situations and discussions in which many different opinions are to be addressed, but such gatherings may not be as conclusive as those that do not involve semantic arguments. If all involved parties have a mutual starting point, a broad spectrum of ideas can be contained in a focussed and effective discussion.

The Hart-Miller Island example in chapter five, section 5.4.1, regarding terminology differences with “contaminants,” “disposal,” and “nutrients,” is one of many examples of poor collaboration of definitions for terminology. The barrier of mutual understanding can be lessened through communication and agreement. Descriptive terminology can be used in place of previously used terms whose definitions were incongruent – “sludge” and “dredge spoils” for instance. As for terms still in use, clear and descriptive definitions must be greed upon by all organizations for which those terms are involved.

The mutual understanding barrier can also be lessened through analysis of the hindrances of public opinion – responsibility, education, and appearance – and of policymaking – complexity, visibility, and incompatibility. Communication is the major underlying solution to the mutual understanding barrier, and communication is developed most easily from education. Clearer communication can be brought forth not only through agreeable definitions, but also through an appeasable approach to public opinion.

6.2 Regarding Public Opinion

Public opinion plays a major role in the hindrance to solutions of many environmental problems. Fully understanding the problems and technological solutions is something needed not only by engineers, scientists, and administrators, but also the public, which affects and will be effected by these environmental issues. In order for local public opinion to benefit progressive strides in ecological engineering, two essential elements between the public and the sciences must be improved: responsibility and education. Beginning with the issue of responsibility, the question is raised: who is held liable for what pollutants and who will take the burden of cleanup? Pollution responsibility leads toward pollution prevention; prevention is attainable through the second element: education.

As seen in chapter 5, section 5.2.3, every individual makes waste of some sort or another. The questions now arise: who is responsible for the wastes that humans produce? Are individuals responsible; is the general populous responsible? On the other hand, are the industries that produce most of these consumer products responsible? Also in 5.2.3, it was shown that the United States does not address manufacturers waste responsibility the same way that many European nations do. The complexities of our social systems, including lack of education regarding environmental concepts confuse the issues of pollution responsibility. In order for individuals and communities to understand their involvement in pollution and knowledge of its cleanup, they must be given the necessary information. Education is a necessary element needed to help public opinion support positive environmental efforts as well as aid the understanding of individual responsibility for pollution.

Education is likely to be the most important and effective creator of change. Since its effects can be quite powerful, education is and can be a useful tool in changing public viewpoints. As seen in chapter five, section 5.2.2, organizations such as the Maryland Environmental Service promote education regarding their approaches to pollution solutions. We also have a valuable education resource in our public school system, much of the knowledge for future generations and their opinions can be implemented through public education. Higher education involving interdisciplinary studies in environmental disciplines and their association with other fields of study – chemical and materials science, engineering disciplines, economics, etc. – promotes understanding of technological and analytical interconnections of non-environmental and environmental fields. This understanding can lead to overcoming the mutual knowledge barrier. As for those presently living with environmental problems, education can come from libraries, the Internet, public meetings, legislation, and even from those companies who are trying to create solutions to those problems. Support of education from these groups, companies, and industries can also aid the companies themselves by advertising through education which will make the public aware of industrial ecological cycles and push public opinion toward their support.

Unfortunately, some people, whether through lack of education or caring, only look at the appearance of a technology or method and will not consider any lasting or preexisting effects of that object or action. Because of this, those working in any ecological engineering discipline must make the products or solutions in that discipline appeasable to the general public. Recycling efforts have continually changed in the past and are now presented in a way that is appealing. Large industries – McDonalds, Saturn, 3M – have used "environmental friendliness" concepts to gain public approval and support. Attractive relations with the public can have a major effect on its viewpoints. When presented well, companies and agencies committed to solving environmental problems can achieve great amounts of support from public opinion. It is the general principle of marketing and a form of persuasive education that can aid the futures of pollution solutions in the disciplines of ecological engineering.

Issues of public opinion, when analyzed through elements of education and responsibility, lead to policy and economic hindrances that can reinforce the mutual understanding barrier. The hindrances in policy issue involve complexity, visibility, and incompatibility of environmental and socioeconomic principles.

Similarly, the identification of pollution sources allows for greater accountability. Sources may be useful in a scientific sense but the accountability they allow is needed in the current structure. Without accountability it is nearly impossible to argue the need for changes by individual pollutants. Analysis methods and accountability are two areas in which environmental action can bridge the gap of incompatibility.

6.3 Regarding Policy

It becomes more apparent that current policies, especially social, economic, political, and legislative policy, tend to encumber rather than facilitate the progress of environmental disciplines. This is due in large part to three factors: complexity, visibility and incompatibility. The size, intricacy and gradual rate of change of the environment, make it difficult to reconcile with the current short-term economic, social and political infrastructure.

Complexities that are inherent in the ecosystem and in our interactions with it present problems of confusion. It is almost impossible to pinpoint each interaction that every individual has with his or her local environment as well as the global ecosystem because the principles of eutrophication with regional environmental niches are inherent in man's daily life. Since it is almost impossible for every person to understand the entirety his or her effects on the environment, the understanding of specific elements of the complex structure of our ecosystems can be promoted with long term education efforts. These elements, on an individual level, include daily water use, re-useable waste production, and energy consumption. On a more commercial or industrial level, an understanding of resource utilization and waste reuse can also be promoted. Chapter five, sections 5.2.2 and 5.2.3, show that for the Chesapeake Bay, fertilizer application methods in agriculture, a resource utilization concept, can be improved. Educating chicken farmers, for example, to plant more vegetation around their property to absorb run-off from manure piles is a way to help curb the flow of contaminating nutrients into the Bay.

Unfortunately, convincing individuals to change their routine practices is not the easiest of tasks. The lack of visibility and awareness of the extent to which simple changes can solve complex problems – that is, the lack of public knowledge – reduces progress in solving them. Before a willingness to change can occur, education must be prevalent. Understanding the importance of change breaks down the mutual knowledge barrier spoken of earlier, and from that, ecological problems and their solutions become visible.

Legislation can act as a catalyst for promoting this environmental education as well as a long-term vision of societal impact on the regional environment. The success in environmental management requires advances not only in social aspects of policy, but in economic ones as well. Beyond complexity and visibility, factors exist which make it difficult to unite environmental concerns with current social, economic, and political values – it is difficult to put a monetary value on a local environmental ecosystem.

Without a working ecosystem, human society and our economic systems would not exist. Because the environment must be seen as this valuable resource whose preservation is economically worthwhile, there is a need for modifications of economic analysis – cost-benefit and determination of value. Without being able to describe in quantifiable terms the value of environmental projects, it is difficult to argue for greater resources to fund environmentally beneficial projects. Companies will be far more willing to invest in environmental projects if they see that such action is a profitable investment. The beneficial possibilities of more funding, seen in chapter four with regards to the Chesapeake Bay, are numerous.

With a better understanding of the complexity, visibility, and compatibility of policy and economic issues, the responsibility and education involved with public opinion, and the incongruence in terminology and the use of technologies, the future direction of ecological engineering becomes clearer. From this analysis, it can be concluded that collaboration exists among fields within ecological engineering on a technological and analytical level, but a lack of mutual understanding of these connections is a severe hindrance. This knowledge barrier prevents the development and sustainability of a mutually agreeable future among ecological engineering disciplines. To create a smoothly functioning field of ecological engineering from the disciplines of environmental engineering, environmental technology, appropriate technology and industrial ecology, there must be clarified terminology as well as support through opinion and funding for development and operation of pollution solutions.

7.0 Recommendations

The goal of this project from its inception has been to study the unity within the disciplines of ecological engineering and find areas in which ecological engineering has barriers that prohibit its forward movement and future sustainability as an effective conglomerate method of implementing environmental solutions. To accomplish this, contaminated sediment removal from the Baltimore Harbor area of the Chesapeake Bay was used as a case study in which we could examine environmental engineering, environmental technology, appropriate technology, and industrial ecology in real-life context.

As discussed before, these four areas are the primary makeup of ecological engineering and a certain level of collaboration exists among them on a technological and analytical level. Unfortunately, a lack of mutual understanding of these connections is a severe hindrance. This knowledge barrier prevents the development and sustainability of a mutually agreeable future among ecological engineering disciplines. Our recommendations are, therefore, concerning improvements in education and communication. The National Science Foundation can give support to those elements by aiding projects that promote public ecological education, industrial cooperation, and local public awareness, responsibility, and involvement.

As discussed in chapter six, lack of clarified terminology acts as a substantial hindrance to collaboration of the disciplines within ecological engineering. The National Science Foundation can help to prevent this by supporting projects that attempt to develop unified and useable terminology. Efforts of the Foundation to ensure collaboration for environmental engineering, environmental technology, appropriate technology and industrial ecology, through project support will set an example to other organizations and companies wanting to promote useful solutions to environmental problems.

Through the use of funding, the National Science Foundation can promote projects that seek to increase the collaboration among ecological engineering disciplines through sharing of necessary information. Promoting projects whose sole purpose is to study communication, information sharing and mutual agreement to work toward unity of understanding – rather than simply technology and analysis – among environmental disciplines is a major step to a sustainable and unified future of those disciplines. Education projects should include those that promote collaboration between individuals and industries on preventing sources of contaminants. Not only must communication develop among environmental disciplines, communication is also needed between ecological engineering and the outside world. Such collaboration would itself lead to implementation of environmentally friendly practices and would also develop relationships, between the regional populous and involved industries and organizations, that could sustain and promote environmental advancement.

The goal of education programs and projects, funded by the National Science Foundation, should be to educate the public about their responsibility to the environment and how the public can do its part to eliminate pollution and clean up what pollution is already present. Curriculums for this should be developed for the current adult population as well as children and students still in school. For children and students in school, an emphasis should be to mix in environmental awareness with daily education. Currently the Federal Water Quality Association is starting a workshop for Washington

D.C. area teachers to achieve more environmental awareness in class rooms right now. Each teacher will be trained to teach water quality units in their classrooms, from early grade school up through high school. For adults, education could come in forms informative pamphlets in the mail, public environmental rallies, or even television programming.

Projects that are exemplary of ecological engineering can also promote environmental advancement. The Foundation should support these projects that are able to develop the facilitation of the collaboration of ecological engineering by creating paths of communication, technology sharing, and conglomeration of missions or goals of many related organizations and industries that effect certain regional environments. Funding these projects will demonstrate to industry, the local public, and environmental groups the benefits of using the ecological engineering process, the systems approach to environmental management which considers the environment as a significant and participating agent in its own preservation.

On a more local level, regarding contaminated sediment removal in the Chesapeake Bay, funding of projects promoting the involvement of ecological engineering principles could benefit the area greatly. Because application of ecological engineering is broad and all encompassing, we recommend a reorganization of existing efforts to clean up and prevent further pollution of the Bay. This could be accomplished through the development of a united organization – consisting of present environmental groups, foundations, organizations, local residents, regional industries, and all others involved in Bay pollution creation and cleanup – much like what the EPA once attempted. Such an organization can promote all principles of unity in ecological engineering – education, unified terminology, and a sustainable future.

The Environmental / Ocean Systems Program of the Bioengineering and Environmental Systems Division of the National Science Foundation can, therefore, improve the quality and sustainability of ecological engineering efforts through support in three areas: local public awareness, industrial cooperation, and ecological education. First, support local educational programs that promote the understanding of individual waste and contaminant production. Working in conjunction with the Directorate for Education and Human Resources may aid with the promotion of such projects. Second, support mutually beneficial programs for regional industries that incorporate the principles of industrial ecology. These include education programs as well as research and development projects. Finally, support programs that combine the knowledge and efforts of industries, public organizations, and other environmentally involved groups. Such programs should specifically involve issues of responsibility, in order to initiate solution efforts.

Appendix A (N.S.F.)

The majority of the following information came from public information from the National Science Foundation's web-site: www.nsf.gov (10/27/98), brochures at the Foundation, and information from individuals at the Foundation.

A.1 Mission of the National Science Foundation

The impact of science and technology during World War II led to Congress' realization that the United States had to assert a leading role in the world's scientific community. As a result, Harry S. Truman signed the National Science Foundation Act of 1950 (Public 81-501). This act created the National Science Foundation (NSF), an independent federal agency dedicated to the advancement of science and technology. By establishing the National Science Foundation, the Federal Government recognized that support of long term research in science and engineering contributes to the strength and well being of the nation.

Research discoveries precede and underlie advancements in many important areas of federal responsibility, including national health, economic growth, energy use and environmental management, and agriculture. Thus, the Foundation was created to support and promote the progress of science, mathematics, and engineering. This broad mission includes support for basic research as well as science and technology education. The National Science Foundation also encourages cooperation with the international scientific community and is committed to expanding the number of scientists, engineers, and science educators in the United States.

A.2 NSF Research

The National Science Foundation supports research in academic institutions, private research firms, industrial laboratories, and major research facilities and centers. The goals of research supported by the National Science Foundation include increased and expanded knowledge, excellence in education, economic competitiveness, innovation, productivity, and improved quality of life for all. The foundation supports research in the following fields:

- atmospheric, earth and ocean sciences
- behavioral and natural sciences
- biological and environmental sciences
- engineering sciences
- computer and informational sciences
- mathematical and physical sciences
- science and engineering education
- social sciences and economics
- inter-disciplinary efforts in the above fields

A.3 Education and Human Resources

The National Science Foundation recognizes the increasing importance of basic scientific and mathematical literacy in the United States. For this reason, the National Science Foundation is strongly committed to promoting education in science, mathematics, and engineering at all levels. Not only does the National Science Foundation fund graduate level research, but it also gives awards for creative engineering, and offers fellowships to undergraduates. The foundation has public outreach programs as well; they are intended to improve scientific and technical awareness in the nation. These public programs also encourage underprivileged individuals and minorities to pursue careers in the sciences and engineering.

A.4 Structure of the National Science Foundation

The National Science Foundation is governed by the National Science Board, a twenty four-member board appointed by the President of the United States and subject to Senate approval. The President also appoints a Director of the National Science Foundation for a six-year term as well as a Deputy Director and Assistant Directors. Almost 2,000 other full-time employees help administer the National Science Foundation.

Within the Foundation, there are nine directorates, each concerning a different field of science and engineering. Each directorate is subdivided into divisions, which are in turn divided into specific program offices. The nine directorates of the National Science Foundation are as follows:

1) Directorate for Biological Sciences
2) Directorate for Computer and Information Science and Engineering
3) Directorate for Education and Human Resources
4) Directorate for Engineering
5) Directorate for Geosciences
6) Directorate for Mathematical and Physical Sciences
7) Directorate for Social, Behavioral and Economic Sciences
8) Office of Budget, Finance, and Award Management
9) Office of Information and Resource Management

The research projects supported by the programs in the Biological Sciences Directorate as well as the Behavioral, Social and Economic Sciences Directorate are designed to strengthen scientific understanding of biological and social phenomena. Research in these directorates includes many areas, from fundamental molecules of living organisms to the complex interactions of human beings and societal organizations.

Programs in the Directorate for Computer and Information Science and Engineering (CISE) improve fundamental understanding of information processing and enhance the training of scientists and engineers who contribute to and develop that understanding. This directorate is inherently multi-disciplinary, supporting computer and informational scientists and engineers, electrical engineers, mathematicians, and artificial intelligence scientists.

The Directorate for Engineering supports research to promote the progress of engineering and technology, and to ensure national prosperity and security. This directorate is comprised of eight divisions, each consisting of various engineering programs. Our particular project falls under the Environmental / Ocean Systems program, directed by Dr. Edward Bryan (environmental engineering), Norman Caplain (ocean systems), and Dr. Fred Thompson (environmental technology). The Environmental / Ocean Systems program lies in the Bioengineering and Environmental Systems division, a division that exists in the Directorate for Engineering. The Bioengineering and Environmental Systems division is primarily concerned with impacts of human activities that may adversely affect the quality of water, air and land.

The Directorate for Geosciences and the Directorate for Mathematical and Physical Sciences deal with research and development in pure and applied sciences.

Research in the Directorate for Geosciences is supported to increase the scientific knowledge of the natural environment on Earth and in space. Research here also deals with the various effects of human activity that interact with this environment – geographic layout of cities, seismic activity, and cartography, for example. The Office of Polar Programs (a separate division) stemmed from this directorate. The Directorate for Mathematical and Physical Sciences aims to develop a fundamental understanding of the physical laws that govern the universe. Research results lay the groundwork for the technological developments upon which our economic and social well being depends.

The Directorate for Education and Human Resources has four major long-range goals. First, it helps ensure the best possible professional education in science and engineering. Second, it helps ensure that college-level opportunities are available to broaden the science backgrounds of non-specialists. Third, it support informal science education programs for the public, and finally, it helps ensure that high quality, pre-college education in science is available to every child in the United States.

The Directorate for Social, Behavioral, and Economic Sciences combines National Science Foundation activities to promote healthy international relations. Programs here study science and technological policy issues as well as collect, analyze and publish data on the status of the nation's science and engineering resources. This directorate helps to provide opportunities for small business firms to participate in National Science Foundation supported research and to extend greater research opportunities to all segments of the scientific community.

A.5 Proposal Review

Each year the National Science Foundation receives approximately 30,000 proposals for research and graduate fellowships, of which, roughly 9,000 awards are given. The Foundation gives awards for research in engineering and the sciences. Each awardee is responsible for conducting the research and preparing the results for publication; therefore, the National Science Foundation does not assume responsibility for such findings or their interpretations.

Most proposals come to the National Science Foundation from organizations and educational institutions rather than individuals. However, individuals may submit proposals under certain circumstances; the foundation welcomes proposals on behalf of all qualified independent researchers. They also strongly encourage women, members of minority groups and handicapped individuals to compete for National Science Foundation awards. Proposals that encourage collaboration between industry and university researchers, and between state and local governments are also sought after.

In deciding which projects to support, the National Science Foundation relies heavily on the aid of advisory committees, outside reviewers, and other experts. Proposals for support are assigned to the most appropriate division or program office. A peer review system and advisory committees made up of over 59,000 scientists, engineers, educators, nonprofit researchers, and industrial organizations advise on which proposals to support. This review system is used to ensure that the decisions reached are fair and informed. To further assist this decision making process, a set of criteria has been established for the review and evaluation of proposals. These criteria are designed to ensure fair selection of the most meritorious research projects.

The two criteria are as follows:

1) *Intellectual Merit*: The project proposed must advance the knowledge and understanding within its own field or across different fields. The proposal team (or individual) must be qualified; this is considered mostly with regards to the quality of prior work. The proposed activity must suggest and explore creative and original concepts. The project must be well organized and there must be sufficient and necessary resources to complete it (NSF, 1998).
2) *Broad Impacts*: The proposed activity must advance discovery and understanding as well as promote teaching, training, and learning. It should be able to enhance the infrastructure for research and education (instrumentation, networks, and partnerships) and the results should be disseminated broadly to enhance scientific and technological understanding. The proposed activity must broaden the participation of underrepresented groups (those of gender, ethnicity, disability, etc.) as well as benefit society in general (NSF, 1998).

A.6 NSF Budget Information

The funding for National Science Foundation research awards are derived from the Foundation's annual budget. For the fiscal year 1998, the National Science Foundation requested a $3.367 billion budget from Congress. The current plan is for approximately $3.457 billion. The Foundation's approved budget for the fiscal year 1999 is $3.672 billion. Including grants to more than 2,000 colleges, universities, and research institutions, funding from the National Science Foundation accounts for approximately twenty percent of federal support for basic research at academic institutions.

The Engineering Directorate, in which the Bioengineering and Environmental Systems Division lies, has an annual budget of approximately $364 million. Almost $1.6 million of this is allotted to the Environmental / Ocean Systems program, in which we are working.

Appendix B (Interviews and Contacts)

B.1 Interviews List

Because of developmental changes in the subject matter of this research project, the lineage of interviews we conducted was not exactly transparent. The following individuals and organizations were either directly involved in ecological engineering issues regarding the Chesapeake bay, or had knowledge of or contacts with relating issues and individuals.

National Science Foundation Liaisons (10/26/98 –12/4/98)
Bioengineering / Environmental Systems Division
Dr. Edward Bryan (Environmental engineering)
Dr. Fred Thompson (Environmental technologies)
Norman Caplan (Ocean systems)

- Contact resources, Ecological Engineering disciplines and principles

Dr. John B. Scalzi (10/30/98) U. S. Department of Transportation

- WPI alum, contact resource, Construction materials (industrial ecology)

Eugene Demichle (11/3/98) Water Environment Federation

- Wastewater treatment (environmental engineering), Industrial interdependence (industrial ecology)

Karen Waldvogel (11/5/98) U.S. Forest Service

- Contact resource, Environmental regulations, Terminology discrepancies (ecological engineering)

Blake Velde (11/5/98) U.S. Forest Service

- Contact resource, Specialization problems (ecological engineering), Risk assessment (environmental technology)

Dr. Steven Spect (11/5/98) U.S. Department of Interior

- Contact resource, Policies (ecological engineering)

Robert Bastian (11/6/98) Environmental Protection Agency

- Wastewater treatment, Water contamination (environmental engineering)

Jen Aiosa (11/10/98) Chesapeake Bay Foundation (Maryland Office)

- Contact resource

Dr. Kent Mountford (11/16/98) EPA Chesapeake Bay Program

- Chesapeake Bay background, Nutrients and other contaminants (ecological engineering)

Wayne Young (11/13/98) Maryland Environmental Service

- Legislation, project limitations, Contact resource

Mark Mendelson (11/12/98) Army Corps of Engineers

- Contact resource

David Bibo (11/17/98) Maryland Port Authority

- Contact resource

R. Shane Moore (11/17/98) Maryland Environmental Service

- Heart-Miller Island (appropriate technology, environmental engineering)

Dr. Neil Seldman (11/18/98) Institute of local Self Reliance

- Sustainable development (appropriate technology, industrial ecology)

Beth McGee (11/23/98) Department of Interior, Fish and Wildlife Service
Chesapeake Bay field office

- contamination in Baltimore Harbor (ecological engineering)
- contaminants and soil characteristics

B.2 General Interview Questions

-- *On company, organization, or agency background*

1) With what issued does this (company, organization, agency) deal?
2) What is the history/background of this (company, organization, agency)'s concerns?
3) How long have you been a part of this (company, organization, agency)?
4) What is your role in your (company, organization, agency)'s concerns?

-- *On personal background*

5) What is your personal background? Education? Work experience?
6) How would you define: Environmental Engineering, Environmental Technology, Industrial Ecology and Appropriate Technology?
7) What is your experience in these areas?

-- *On the Chesapeake Bay Case study*

8) What do you know about dredging in the Chesapeake Bay?
9) What do you know about disposal of contaminated sediment from dredging?
10) How does dredging in the Chesapeake relate to the four disciplines of industrial ecology, environmental engineering, environmental and appropriate technology
11) How do you see them interrelating in consideration to this specific case study?
12) How do you see these four topics relating to one another in a general sense?
13) Any barriers? (Both specific and General)
14) What are the social repercussions, if any?, from the process and the result?
15) What would be an appropriate way to judge the success or failure?
16) What might you recommend in consideration of the issue?

Appendix C (Glossary)

Because many words or terms used in this report may have vague or multiple meanings, it is necessary to define them in a more precise manner. The large part of these definitions came from Webster's English Dictionary 1998.

Bio-solids: precipitated solid matter produced by water and sewage treatment processes; sludge.

Contaminate (contaminants): to make unfit for use by the introduction of unwholesome or undesirable elements; pollute.

Discipline(s): a field or fields of study.

Dredging: to dig, gather, or pull out in order to deepen (as a waterway) with a dredging machine.

Ecology (ecologies, ecological): a branch of science concerned with the interrelationship of organisms and their environments. Also, the totality or pattern of relations between organisms and their environment.

Ecosystem: the complex of a community of organisms and its environment functioning as an ecological unit.

Effluent: waste material (such as liquid industrial refuse or sewage) discharged into the environment especially when serving as a pollutant. An outflow into a water source.

Environment (environmental): the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival as well as the aggregate of social and cultural conditions that influence the life of an individual or community.

Engineering: the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people; the design and manufacture of complex products.

Estuary: a water passage where the tide meets a river current; especially an arm of the sea at the lower end of a river (eg: the Chesapeake Bay).

Eutrophication: the process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen. This usually results in a domino effect of dying aquatic organisms because of lack of oxygen.

Hazardous (biohazard): involving or exposing one to risk (as of loss or harm).

Industry (industries, industrial): systematic labor especially for some useful purpose or the creation of something of value; a distinct group of productive or profit-making enterprises; manufacturing activity as a whole.

Interdisciplinary: involving two or more academic, scientific, or artistic disciplines

Management: judicious use of means to accomplish an end.

Nutrients: substances or ingredients that influence modifying the expression of the genetic potentialities of an organism. Includes phosphorous, nitrogen, as well as metals.

Pollution: environmental contamination from man-made waste.

Sediment: material deposited by water, wind, or glaciers or the matter that settles to the bottom of a water body.

Sludge: precipitated solid matter produced by water and sewage treatment processes; bio-solids.

Spoils (dredge spoils): something valuable or desirable gained through special effort or opportunism. Useable sediment material removed from a water body floor.

Technology (technologies, technological): the practical application of knowledge especially in a particular area or a capability given by the practical.

application of knowledge. Also the specialized aspects of a particular field of endeavor

Waste: damaged, defective, superfluous material, or unwanted by-product produced by a manufacturing process, chemical laboratory, nuclear reactor, etc. Also, refuse from places of human or animal habitation; garbage, rubbish, excrement, sewage.

Watershed: a region or area bounded peripherally by a divide and draining ultimately to a particular watercourse or body of water.

Wetland: land or areas (as tidal flats or swamps) containing much soil moisture.

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*Interviews conducted in the DC area are referenced in Appendix B. See section B.1 for this information.