

Proposal for  
NSERC's Environmental Design Engineering Chair  
creating an

## Urban Systems Environmental Design Centre (USED Centre)

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Signatures

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L.Otten, Director, School of Engineering



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M. Rozanski, President, University of Guelph



*Signatures confirm that the applicant and the university accept:*

- *NSERC's conditions governing grants as outlined in NSERC's Researcher's Guide applicable to any grants made pursuant to this application; and*
- *the commitment to provide the funds and other resources indicated in the application over the five-year life of any approved chair.*

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## Part 1: University of Guelph's Design Strategy

The **vision** for Environmental Design Engineering at Guelph in the future, the **current status of engineering design** at Guelph and the **structure** of the Chair to accomplish the goals are presented in the following sections.

### 1.1 Vision for Environmental Design Engineering at Guelph

The environmental challenges of today and tomorrow derive from every aspect of human behaviour. The prevailing environmental challenges include air issues (e.g. global climate change, ground level ozone and urban smog, stratospheric ozone depletion), water issues (e.g. resource depletion, pathogens, nutrients, metals, persistent organics) and waste issues (e.g. landfills, composting, recycle/reuse, packaging). Most of the challenges are complex and few can be solved by the actions of a single individual, a single industrial operation or a central treatment plant. Most of the challenges are interdependent and few can be solved in isolation. The most effective solutions will result from an integrated approach that spans all sectors and all sources of the problem. As a long term goal, the field of Environmental Design Engineering must develop integrated design capabilities that span all sectors, sources and types of environmental vectors. Environmental Design Engineering education must advance to ensure that our graduates recognize the complex reality, are prepared to make design decisions in this reality and, ultimately, who will be the drivers of this advancement.

We propose to use an Urban Environmental Air/Water/Waste-Shed as a LIVING, DYNAMIC DESIGN LAB to provide a framework for developing advanced Environmental Design Engineering capabilities that recognizes the breadth of challenges and the demand for integrated design capabilities. The urban environmental air/water/waste-shed will also provide the framework for delivering Environmental Design Engineering education. The Environmental Design Engineering Chair at Guelph will become an Urban Systems Environmental Design Centre (USED Centre). The city of Guelph will act as the case study. The 'city' meaning the entire community - homes and residents, industry, institutions, service sector, immediate surrounding environment and municipal infrastructure.

The participants in the USED Centre will include faculty from engineering, economics and landscape architecture, students from first year to doctoral candidates, engineers and non-engineers, plus community participants including the 'source' and 'service' sector. The USED Centre will work on individual environmental design problems faced by the community while building integrating Environmental Design Engineering experience and capabilities. Through case study and problem-based learning styles, the students will advance their Environmental Design Engineering education through active involvement in individual problems and the development of integrated solutions.

This framework provides an opportunity to achieve all of the goals for advancing Environmental Design Engineering education and for advancing the field of Environmental Design Engineering. Furthermore, it provides ample opportunity to develop educational material for exchange through the C-DEN/RCCI network, and the opportunity to collaborate and promote engineering design with the external community. The USED Centre will generate:

- graduates with experience in Environmental Design Engineering,
- a wide range of design solutions for our outside partner's products and processes, and
- advanced Environmental Design Engineering capabilities to minimize the overall emissions/impact (air, water and waste) of a community.

All of which will be communicated to other universities and communities for further educational and environmental rewards.

The community of Guelph is ideally suited to this challenge. The City has a population of

approximately 100,000 and a diverse economic base. Industry includes manufacturing companies (e.g. Blount, Linamar, ABB), bio-process companies (e.g. Sleeman's, McNeil Consumer Healthcare, Better Beef), and chemical process companies (e.g. Huntsman, PolyCon). Institutions include the University of Guelph as well as three large hospitals. It is comprised of very old residential areas as well as many brand new sub-divisions. The municipal infrastructure includes a state-of-the-art wastewater treatment plant, a sanitary landfill and the world renowned Wet-Dry recycling facility. The community has demonstrated a willingness to take risks for environmental motives and perceives itself as a 'green' community.

The University of Guelph's School of Engineering is also ideally suited to this challenge. The Environmental Engineering program was the second such undergraduate program to receive accreditation and has produced the largest number of baccalaureates in Canada. The non-departmentalized School is ideally suited to interdisciplinary approaches and the programs offered by the School are interdisciplinary in character. About 70% of the current faculty have backgrounds in the disciplines of Chemical, Civil, Electrical and Mechanical with the remainder from Systems Design, Agricultural, Biological and Water Resources Engineering. This interdisciplinary character fits completely with the diversity of environmental challenges that are faced by society and the skills necessary to develop integrated solutions.

This interdisciplinary character of the School of Engineering, the non-departmentalized structure coupled with the foundation of the traditional disciplines makes Guelph ideally suited for the Environmental Design Engineering Chair. The students that we educate, the products we develop for our outside partners, and the instructional materials that we exchange with other institutions will span many engineering disciplines.

The University of Guelph's specific goals are to:

- I. Develop integrated Environmental Design Engineering capabilities
- II. Deliver integrated Environmental Design Engineering education
- III. Develop Environmental Design Engineering solutions for a wide range of challenges faced by our local community
- IV. Advance Environmental Design Engineering skills in particular and Design Engineering skills in general for all students
- V. Strengthen our relationship with the outside community particularly the local economy
- VI. Increase our profile within the academic engineering community through C-DEN/RCCI

Advances in design training at both the undergraduate and graduate level are specific foci of Goals II and IV but depend heavily on the success of all of the goals. Design and development activity is the focus of Goals I and III but has links to other goals. Collaboration will be essential for goals V and VI and is important for the success of Goals I-IV as well. Promotion will also be most closely linked to Goals V and VI. Specific details in relation to each of these goals is provided in Part 2 of this proposal.

## **1.2 Background and Current Status of Engineering and Engineering Design at Guelph**

The engineering programs at the University of Guelph have their roots dating back to 1874 as part of the Ontario Agricultural College. Today, the School of Engineering (SOE) offers four CEAB-accredited undergraduate engineering programs: Biological Engineering, Engineering Systems and Computing, Environmental Engineering and Water Resources Engineering. These programs are delivered through a common core (about two-thirds of the courses) and program specific courses and electives. In addition, SOE offers Masters programs by thesis and by course-work and Doctorate programs in these areas.

The University of Guelph is an international leader in life sciences, agriculture, veterinary

medicine and the environment. Guelph's engineering programs reflect and complement the nature and strengths of the University. Throughout Guelph's engineering programs long history, life sciences have been integrated into the curriculum. SOE offers unique, interdisciplinary engineering programs. For example, the Biological Engineering combines elements of chemical and mechanical engineering with life sciences (e.g. microbiology and biochemistry) to produce graduates who have been successful in a wide range of careers including bio-process engineering and biomechanics design. The Environmental Engineering program at Guelph combines elements of Civil, Chemical, and Mechanical Engineering with doses of life and earth sciences.

Guelph's four undergraduate programs provide a liberal engineering education with strong emphasis on problem solving and engineering design. Our graduates have a strong foundation in fundamental engineering skills, they have excellent people and team skills and they have excellent communication skills. Our alumni are employed in a very broad spectrum of employment.

One illustration of our student's interdisciplinary team skills is the design of a Solar Distillation Unit by David Cuillerier, Russell Ramsay (both Engineering Systems and Computing students), Tim Robertson and Paul Khanna (both Environmental Engineering students). This undergraduate team won the Gold Medal award at 1995 Owens-Corning Global Design Challenge (an international competition including M.I.T., Hong Kong University and Domus Academy).

Engineering design education at Guelph is delivered through three elements: a core sequence of four design courses taken by all students, a selection of program specific design courses and design elements within many of the other engineering courses. In the latest CEAB accreditation report (1998), the design content of our programs averaged 358 AU's well above the CEAB minimum.

The general engineering design education objectives are to graduate students who can:

- solve engineering problems creatively,
- take into account environmental, safety, sustainability, societal and ethical considerations,
- work effectively in a multi-disciplinary team environment,
- communicate effectively.

The core sequence of four design courses let the students learn design by doing design. In first year, the problems are fairly well-defined and general engineering in character. By fourth year, the students are encouraged to work in multi-disciplinary teams on open-ended problems of outside clients. The lectures in each of the courses provide the students with insight into the design process, communication tools and techniques, sources of and access to technical information, project management, team skills and economic aspects.

Undergraduate students take at least two additional, discipline specific design courses. These courses give students design experience in specific areas relevant to their fields.

Design activity at the graduate level currently includes some design elements within graduate courses, many design oriented M.Eng. projects and some research in the design area.

### **1.3 Positioning and Role of the Design Chair**

The USED Centre will be comprised of a core of four faculty dedicated to the Centre, a network of additional existing engineering faculty, a few faculty from outside of engineering, a new technician plus support from existing technicians, undergraduate and graduate students and an advisory body from the community. The four core faculty will include Professor Warren Stiver, the proposed Chair, and three new, tenure-track faculty appointments. The network of additional engineering faculty includes the members of the local C-DEN/RCCI committee which includes all of the instructors of the core design sequence courses. Faculty from outside engineering include members from economics and landscape architecture. An advisory body will be created consisting of 8-12 individuals from local industry (bio-sector, manufacturing sector, environmental sector), from the consulting sector and from

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the municipal sector. Prof. Stiver will direct the activities of the Centre as a Chief Administrative Officer. A partnership style of management will be used to drive the design work of the Centre drawing on the individual expertise of each of the participants as needed.

The existing Design sub-committee of the School's Curriculum committee, together with the new local C-DEN/RCCI committee and the Design Chair members will form a strong team to drive design at the University of Guelph. This team of approximately 10 faculty, about one-third of the School's engineering faculty, will work together to increase all dimensions of the School's design activity. The team is large enough to form a substantial critical mass and to establish a high profile for engineering design at Guelph.

The Design Chair will integrate into the programs of all of our students as a result of the non-departmentalized nature of SOE and as a result of the multi-faculty partnership style of the Centre. SOE has a current undergraduate enrolment of approximately 600 students, a projected population of 800 by the year 2002 and a projected growth to nearly 1000 students as a result of double-cohort in the province of Ontario. Since SOE is non-departmental in character, the activities of the USED Centre will benefit all engineering students at Guelph.

## Part 2: Chair's Action Plan

Specific activities associated with **training, design and development, collaboration** and **promotion** are provided in the following sections. Overall **milestones** and **performance indicators** are provided at the end.

### 2.1 Training

The educational goal is to develop engineering graduates who possess integrated design capabilities to solve complex environmental problems (GOAL II). As part of achieving GOAL II, it is necessary to strengthen both general engineering design education and specifics of Environmental Design Engineering education (GOAL IV). The activities planned to achieve these goals for the Undergraduate Engineering students will be presented first followed by the activities for Graduate Engineering program.

#### 2.1.1 Undergraduate Engineering Design Education

Our employers and alumni tell us that our students already have a sound understanding of the design process, with good problem solving abilities, teamwork and communication skills. Like most engineering students, their education has emphasized theoretical material with less emphasis on practical items. The USED Centre will be a living, dynamic laboratory setting that will provide students the opportunity to work and learn in real-world, multi-faceted situations. In the sections that follow the activities to achieve GOALS II and IV are provided. The first section focuses on the nature of the environmental design engineering projects that will be derived from the community and the building of integrating design skills in the students. The later sections (creativity, practicality and integration of engineering science into engineering design) provide specifics towards strengthening the student's design skills.

##### 2.1.1.1 Integrating Design Capabilities and Community Environmental Design Problems

The field of Environmental Design Engineering must develop integrated design capabilities. Integrated solutions are built upon a foundation of individual design solutions. The students will have the opportunity to participate in individual design solutions during their first two years and begin developing integrated solutions in their third year. In their final year, the advancement of their integrated environmental engineering design skills will conclude in a new fourth year, integrated Design course and the student's final design projects.

The projects developed for the first and second year students will be specific projects of a fairly defined scope. These student's exposure to integrated design will be the understanding of how their individual project fits into the whole solution and their understanding that all large engineering design projects are broken down into numerous individual design components.

For example, as part of the discussions of the USED framework with local industry, one company requested a design of solar panels on the roof of their plant to generate electricity. They are a big energy consumer and they are concerned about global climate change and the impact on their operations. This type of project is well suited to first or second year students. Students will quantify the costs, the energy generated and the corresponding carbon dioxide emission reductions. By extending the project to include not only the local company expressing interest but also to the university's energy needs and the heating requirements of a backyard pool, then the project can serve the data and design needs of the USED Centre. The extension can be readily done by assigning different application sites to different student teams. The overall result is the students get an excellent project to work on with real

constraints and the industry and USED Centre get the necessary cost-environmental performance relationships. The input required by local industry is the provision of site data and the provision of student tours. The benefit is design solutions to their problems.

By third year students are ready and capable of dealing with more open-ended project scopes and can begin considering problems in a holistic manner. A suitable project might consider the treatment of a high-strength wastewater from a local bio-process industry. In the past, a project of this type might have a scope that allows for on-site treatment alone. A broader scope would consider on-site treatment and treatment at the central, municipal plant. Students would analyse the performance and incremental costs of central plant treatment in comparison to on-site treatment. Ultimately, more creative and more effective solutions may become apparent as the students consider the problem in this larger context. For example, on-site storage during the day with release to the central plant during the night may result in lower capital costs while providing greater stability at the central treatment plant. The more often students see superior solutions deriving from a broader scope, the more likely they are to define broader scopes in future projects.

At the fourth year level, reduction of greenhouse gas emissions could serve as several final design projects. The problem would be stated in an open-ended manner such as design a means to reduce the greenhouse gas emissions (direct or indirect) as a result of the overall manufacturing plant's operation. The solutions could encompass greater energy efficiency, alternate sources of energy including the solar panel option and/or a more energy efficient product.

A variation on the theme could be applied to essentially every sector of the community leading to enough projects to keep the School's students busy for many, many years. Equally the theme extends readily to water conservation and water quality issues as well as solid and hazardous waste generation. The key is to develop the relationships with the local community, to ensure that the scope of the projects is a good fit for the students' skill levels and to ensure that both sides interests and needs are addressed.

These alternative solutions will require alternative economic structures. The Engineering Economics (ENGG\*3240) course will be modified to introduce various economic models and strategies (e.g. emissions trading structures) that support more integrated, collective decisions.

A new fourth year course on integrated Engineering Design course will be developed which will extend the concepts of life cycle analysis for a single product, extend the concepts of optimization and process integration and ultimately capture the fundamentals necessary for Urban Systems Environmental Design. The course will prepare students to deal with optimization in complex design situations involving many conflicting constraints and criteria. Economic factors linked to emissions trading and human factors linked to consumer acceptance and adoption must be incorporated into the development of optimal solutions. The course will begin as an elective for all engineering students and eventually become a core course for each of the programs.

#### 2.1.1.2 Creativity.

Creative and innovative engineers must have the dual skills of an imagination to conceive of original solutions while at the same time the ability to filter out the impractical and distill their imagination to the practical, original solutions. 'Beam me up Scotty' maybe a very imaginative solution to our transportation challenges but isn't a creative engineering solution due to practical constraints.

Traditionally acceptance into an engineering program is driven by high grades in math and science. High school math and science courses don't often focus on creativity. Potentially, more creative engineers might be developed by considering demonstrated creativity as a criteria for admission. The University of Guelph has a Profile Form path for admission that currently considers students below the posted cut-off grades but have other attributes or factors that make them worthy of admission. This has been effectively used to admit talented students with demonstrated leadership

skills. Demonstrated creativity will be added as an additional criteria for admission through this Profile Form mechanism. Creative engineers combine experiences often from existing capabilities to create a totally new approach. Experience and breadth of experience is necessary and develops over time. SOE's multi-disciplinary faculty means that each of our students see a mix of engineering disciplines over their career. In addition, the basic sciences and mathematics are taught by the faculty in these disciplines. Overall, the students interact with faculty from a broad range of disciplines. This breadth of experience fosters creativity.

Creative characteristics and capabilities can be cultivated and fostered through encouragement, opportunity and practice. Activities developed to support creative advances will include:

- providing open lab and shop time for the students to physically test their ideas,
- providing Computer-Aided-Engineering tools for the students to test their ideas through modelling,
- providing specific design projects focused on developing creativity distributed throughout the design courses, and
- developing a new creative engineering design course.

A new fourth year elective creative engineering design course will be developed and available to all engineering programs. The course will be interdisciplinary, require the students to take risks, reward risk taking, and ultimately focus on developing new solutions to new and old problems alike. The course would be elective and would suit a student that wishes to strengthen their design skills in a cross-disciplinary, creative manner.

#### 2.1.1.3 Practical Solutions.

Students entering engineering programs today are often academically strong. However, relative to 20 years ago, fewer are likely to have taken a shop course, fewer have done maintenance on their family car and fewer have the practical experience that might come from a family farm. This culture shift diminishes their inherent background and comfort with the practical world. Design, particularly creative design, relies on the judgement and experience to assess what is indeed possible. The Design Chair will improve this dimension through:

- < a large number of tours of outside facilities (a minimum of 10 tours over their 4 years), many of these tied to specific design projects that they will be working on),
- < frequent classroom visits by outside engineers in engineering science and engineering design courses
- < increased hands-on opportunities to build and test their ideas through the lab and shop facilities (at least 4 different building opportunities). There is nothing better for the education of a design engineer then to see your ideas built and tested. The shortcomings are often glaring and the new creative ideas often come fast and furious. Students will see and viscerally understand the reasons for prototypes and the value of iterations in engineering design.
- < a dedicated time slot each week in which the experimental labs and shops are open to all students for their use. Students will be encouraged to use this free time for work linked to a specific course, a design project or for their own hobbies and ideas. Technician support will be provided during this time.
- < develop an extensive series of display cases to house a wide range of engineering components reflecting both historical and current practice. Vacuum tubes to fiber optics, from low emission pump seals to catalytic converters. These displays will be available for use in classrooms but normally located in the student common areas. Creative individuals are generally thought to be able to visualize complex entities more readily.

#### 2.1.1.4 Engineering science integration into engineering design.

Students all too often see their courses as discrete entities; they often fail to see the utility of an engineering science course focused on theory and fundamentals and then ultimately do not bring that engineering science knowledge to bear on a design problem with much depth of analysis. Historically, instructors in the engineering science courses have been limited to the analysis associated with simpler cases such as one-dimensional problems and steady state problems. On occasion simplified two-, and three-dimensional cases and transient cases are considered. The limitation is driven by the numerical demands of the complex 3D and unsteady state cases. However, advances in computer technology and software have stripped away these limitations for many engineering fields. Computer-Aided-Engineering (CAE) has developed in a variety of forms but have the common characteristics of the numerical power to treat multi-dimensional and/or transient problems robustly. This power can be used in both the engineering science and design courses to help the students integrate the engineering science into their engineering designs.

A solid understanding of engineering science fundamentals is key to the creation and development of sound designs. The Design Chair will foster a strengthening of the fundamentals within the engineering science and design courses through the integration of Computer-Aided-Engineering (CAE) software. It is also possible to integrate these tools into the curriculum in a manner that strengthens the student's understanding of the fundamentals, strengthens the student's understanding of the value of fundamentals and can excite the students about the near limitless possibilities that an engineer skilled in the fundamentals with powerful tools and a creative imagination can accomplish.

Fluid Mechanics (ENGG\*2230) is a second year, core course which has countless applications in Environmental Engineering. Cyclones, air dispersion, clarifiers, HVAC, cleaning nozzles all fundamentally depend on fluid mechanics. Water disinfection systems must provide sufficient contact time to kill microorganisms which essentially means that the design of these systems requires knowledge of the distribution of hydraulic residence times. A common simple calculation for the student's in fluid mechanics, for an ordinary, straight, cylindrical pipe, is average hydraulic residence time and the distribution of the hydraulic residence times. However, few disinfection systems are simple straight pipes; thus, the student's aren't equipped to design disinfection units even though they have the fundamental fluid mechanics. The limitation is the student's skills in partial differential equations (PDE's), numerical techniques and the time available to analyse these more complex, real systems. Introducing CAE software into a Fluid Mechanics course removes these limitations and allows the students to directly see the extension of the fundamentals to the real challenge of disinfection contact chamber design. In introducing CAE, the student's would be exposed to its risks (poorly defined mesh or boundary conditions) and its power - the ability to deal with complex 3-D and transient problems quickly and accurately.

Similar changes are planned for many of the other fundamental engineering courses including Material Science (ENGG\*2120) and Heat and Mass Transfer (ENGG\*3430). The Numerical Methods (MATH\*2130) course will be modified to focus on understanding the risks and pitfalls of a given numerical technique and on developing strategies to conduct the appropriate checks and balances.

Successful integration of CAE packages of various forms will take time and will require design style iterations. It is certain that our graduates and practicing engineers will use various CAE packages in ever increasing proportions. Students need to learn how to use these tools intelligently as they explore different design problems over their four years of study.

Examples of CAE tools that will be incorporated into the curriculum include *SuperPro*<sup>®</sup> for process design, particularly bio-process design; *Fluent*<sup>®</sup> combining computational fluid dynamics (CFD) heat transfer and reaction kinetic capabilities to aid design; and *I-Deas*<sup>®</sup> for the mechanical engineering

field combining solid modelling with finite element analysis capabilities for mechanical stress/strain issues, heat transfer and CFD. Guelph has begun introducing these types of advanced packages to the undergraduate program. The goal is NOT to teach software tools (students of today pick these skills up readily) BUT instead to focus on how the design process changes with the power of these tools and how engineering education must change to recognize this new environment. Engineering fundamentals are still essential for engineering education but the fundamentals may well shift.

As an educational tool, the software offers the student the same advantages as the practicing engineer: the ability to test many ideas without the expense of building prototypes. Ultimately, the student engineer and the practicing engineer are freer to be more creative.

### 2.1.2 Graduate Education

The plan is for a minimum of 20 graduate students to be directly active with the Centre on an ongoing basis with a fraction of these directly supported by the Centre. The remaining students will be funded through design grants and contracts of the faculty involved in the Centre.

The graduate students will be working with faculty on the advanced **Design and Development** work that will be discussed in more detail in Section 2.2. This section will discuss the changes to graduate programs in order to advance engineering design education at the graduate level.

#### 2.1.2.1 Graduate Programs.

The School offers three graduate engineering degrees: a course-work Master's program (M.Eng.) which is particularly attractive on a part-time basis to practicing engineers, and research Master's and Ph.D. programs that are typically completed on a full-time basis.

The current M.Eng. program is well structured to develop more design emphasis that would be appealing to practicing engineers. The requirements of the final project course for this degree already encourages students to consider a design project. The key will be to develop a number of new graduate-level design courses and to modify many existing graduate courses to increase their design emphasis. Advanced design facilities and the existence of a critical mass of students and faculty engaged in environmental design will be attractive to practicing engineers. These engineers will bring with them their own design problems, foster collaboration and generally enhance the USED Centre.

The research Master's program will M.Sc. degree is a research thesis degree with many students working in the directions of the research grants of faculty. This degree in principle might act as the vehicle for graduate student 'discovery in design'; however, there is the risk that nothing new happens or no distinction is apparent. To address this a new M.Sc. (Design Eng.) degree will be considered as a vehicle for setting up an alternate structure, stimulate distinctly different 'discovery' and could recognize the highly team based design work.

The Ph.D. degree will continue to provide the highest level graduate degree with these students making a significant contribution to the field of engineering design. Doctoral students conducting research in design will be essential for faculty renewal in engineering design.

#### 2.1.2.2 Graduate Courses.

New graduate level design courses will be developed and the design emphasis increased in some existing graduate level courses. The new courses will include an advanced integration design course that would follow on the concepts developed in the new fourth year course and the results of the USED Centre activities. An example of a course that would see an increased design emphasis is Advanced Fluid Mechanics (ENGG\*6020) through a change from a highly theoretically based one to one focused on advanced design solutions to complex, city of Guelph generated, fluid mechanic problems. For example, the assignments could execute CFD analysis to aid the design of emergency response plans for

spills and fires - a problem of heightened importance in Guelph as a result of the recent industrial fire at Quatic Industries.

A graduate course in 'teaching' design and design philosophies will be created. This course will be analogous to an existing University of Guelph graduate course on university teaching which has proven valuable for graduates pursuing academic careers. This new course would be particularly valuable for our Ph.D. students who will be considering an academic career with emphasis on design.

## **2.2 Design and Development**

The Design and Development aspects will specifically address the Goals I and III of the USED Centre. The activities include advances to the field of Environmental Design Engineering through research by the members of the USED Centre as well as development of solutions to the environmental challenges of our community through a range of design projects. The nature of the challenges requires a team approach drawing on team member's as appropriate for the various project components. The faculty members on the team will include Profs. Stiver and Zytner (Environmental Engineering), Joy (Water Resources), Davidson and Brown (Biological Engineering), Zelek (Engineering Systems and Computing), Livernois (Economics) and Taylor (Landscape Architecture). In addition, the 3 new SOE faculty to be hired will become part of the team. The Design Chair funding will support a number of graduate and summer students including students in the Social Sciences.

The direct products of the Design and Development aspect of the USED Centre will be:

- a set of Urban Systems Environmental Design tools supporting integrated design capabilities at the community level,
- numerous individual environmental design solutions for the community of Guelph, and
- highly qualified personnel in the form of graduate students and faculty. Faculty experience will lead to an evolution in undergraduate design experiences through a greater emphasis on holistic approaches and case studies to illustrate opportunities and successes. Graduate students will contribute to the engineering community as well as provide for faculty renewal at our sister institutions.

### *2.2.1 Integrated Design*

Conducting integrated environmental design at an Urban Systems level means considering all sectors, sources and types of environmental vectors within a community as both part of the problem as well as part of the solution. The best solutions will optimize multiple criteria: the lowest overall environmental impact; the lowest overall cost; highest quality of life; and, most supportive of wealth generation for the community.

Automobiles are now designed as an integrated whole leading to a superior product. Individual products are increasingly being designed on a life cycle basis and individual processes designed with integrated operations. Each of these advances in design approach lead to a superior product available at a lower cost or lower environmental impact. Integrated environmental design at the community level is an extension of these concepts to the larger scale of an urban community. In this extension, many of the concepts of optimising the automobile's design, of life cycle analysis and of integrated process design apply, but there is an additional challenge stemming from the individual autonomy that prevails in the overall urban community. In Canada and much of the world, we do not live in a controlled economy and we enjoy considerable personal freedom; thus, the engineering design of solutions must also consider the likelihood of adopting the remedy. A new, technically sound transportation system to reduce greenhouse gas emissions is a failure if people don't use it.

Consider the challenge of reducing greenhouse gas emissions from the community of Guelph. Every residence, car, company, institution and operation contributes to the overall source and is

responsible for part of the solution. It is not conceivable that the cost to reduce emissions per gram of carbon dioxide at each source will be exactly the same. Thus, the total emission reduction can be achieved by each source acting individually resulting in a higher cost to achieve our overall emission reduction target. Alternatively, a company could achieve its emission reduction through subsidizing bus passes for all of its employees, sharing the cost of a capital investment at another company or supporting a community tree program. The alternatives offer the opportunity for a bigger environmental bang for the dollar.

Continuing with the greenhouse gas emission reduction example, it is necessary to recognize the impact some solutions will have on other environmental challenges. For example, more trees on residential properties will reduce residential energy consumption while at the same time reducing water consumption and phosphorus levels in the stormwater runoff. Environmental design engineers must develop the skills and the tools to consider and quantify the interrelationships among the environmental challenges in the same way that the car design must consider fuel efficiency, NO<sub>x</sub> emissions and salvage recyclability all at the same time as car performance.

Thus, the goal of the USED Centre is develop experience and solutions for integrated design at the community level and to ultimately translate this experience into computer-based design tools. These design tools will have the capacity to handle air, water and waste issues including interrelationships between these.

It will take considerable time and energy to reach this level. A database of current emissions from all sources will be required. Relationships between costs and emission reductions will need to be acquired based on best available practices as well as developed for numerous specific sources. This will be the most time intensive part of the process. Development of various economic models or approaches that will foster holistic decisions at the community level must be explored, developed and tested. The work will be completed in phases with the early phases representing prototype development.

Phase I is proposed to consist of two parts (A and B). Part A will consider reducing greenhouse gas emissions for a system by  $x$  tonnes/a (equivalent to 20% of McNeil Consumer Products Year 2000 emission). The urban system considered for Phase IA will be a more limited system consisting of McNeil, Blount, Guelph City buses and an older subdivision. Part B will consider reducing water consumption for a system by  $x$  m<sup>3</sup>/a (equivalent to 20% of Blount's Year 2000 consumption). The urban system considered for Phase IB will be a more limited system consisting of Blount, Sleeman's, the University and a proposed New Subdivision.

This first Phase will require development of most of the dimensions of the capability while at the same time not overwhelming the task with volume of information and data. Water and greenhouse gas emissions have been selected for these prototype projects based on the recognition that they represent the two most significant global environmental challenges faced by society. The systems selected combine industrial, municipal/institutional and residential sectors. Blount being common to both system sets will support the building of the interrelationships between environmental issues in the next phase.

A key challenge in developing collective, integrated solutions will be managing and allocating costs and benefits. Within Phase I, various economic models and structures will be created and tested.

Phase II will comprise building the second iteration of the tool while at the same time extending the system (adding companies, institutions, etc.), extending to additional environmental vectors and finally building the relationships between environmental vectors. Phase IIA will focus on extending the system by adding companies, institutions, residential areas within the context of water consumption and greenhouse gas emissions. Phase IIB will focus on extending the capability to additional environmental issues (e.g. waste generation, volatile organic chemicals released to air and heavy metals in wastewater). Phase IIC will work towards building the capability to handle inter-relationships with the focus on these inter-relationships being the impact on greenhouse gas emissions.

Phase I will be completed by the end of Year IV at which point Phase II will be initiated. Phase II will be an ongoing activity for many years for the community of Guelph. Following the first period of funding for the Design Chair, the Centre will begin Phase III through application in other communities.

### 2.2.2 *Specific Environmental Design Problems*

The second dimension of the Design and Development work will be the design work on the details of numerous problems that will serve the demands and requirements of the urban community while at the same time establishing a data base of relationships and solutions to be fed into the overall integrating tool.

The work on this second dimension will be conducted by 1<sup>st</sup> year students to PhD students and all faculty active in the USED Centre. First year design students could develop specifications for the size and cost of solar collectors for heating residential pools through to the supply of electricity for a local manufacturer. Part of the design would include the determination of the corresponding decrease in greenhouse gas emissions as well as other pollutants. The collective information from numerous design teams would provide relationships for the integrating tool in terms of cost, emission reductions, space requirements as a function of scale. The integration of the 1<sup>st</sup> year design results may be a project for a graduate student involving the integration as well as detailed checks and cross references.

Final year design student teams will be charged with the open-ended task of reducing energy consumption for a company by 20%. A similar set of water conservation projects will be tackled. Many of these energy and water savings projects will be justifiable on their own right. However, it is likely that prior to implementation, the designs will required further development either by the company or the USED Centre.

Existing Computer-Aided-Engineering (CAE) tools will be used as appropriate to avoid re-inventing the wheel through the tedious process of writing sophisticated numerical code. Process design software will facilitate assessment of process integration opportunities to lessen energy consumption, water usage and waste generation. Computational fluid dynamics facilitates better design of component parts or components of a systems that are more efficient.

The agri-food and biotechnology companies often have very high water demands and generate particularly high-strength wastewater. Clean-in-place programs and sanitizing constraints make minimizing water use a challenge. Advanced engineering design techniques could lead to the development of better spray nozzles to improve washing efficiency (e.g. a clean, sanitized surface using less water and/or time). Or, a redesigned tank outlet to improve drainage efficiency.

Similar design requirements exist in many manufacturing firms that paint or plate parts. As part of the process, it is advantageous if solutions drain rapidly off of the part. In a hexavalent chromium plating operation an effectively drained part leads to less water usage, less hazardous chromium waste and lower costs. Advanced CAE software could aid the design of the optimal part geometry. Ultimately, the spray nozzle design and the part design are variations on a theme and all could be enhanced with the use of CAE design. A key outcome from the *Design and Development* activity will be the demonstration of the potential of advanced CAE to reduce environmental impact in as many applications as possible.

In the field of process design, capital costs often carry greater weight than operating costs. Attempting to minimize capital costs with little regard for operating costs leads to poor designs, that in the long run have higher economic and environmental costs. Industry is thought to be responsible for 30-40% of greenhouse gas emissions which arise from energy requirements, resulting in excessive operating costs. Advanced numerical process design tools provide the opportunity to optimize an entire operation considering all transient scenarios.

The above items highlight some possible types of products and processes that the USED Centre

could creatively explore as design opportunities. The opportunities are endless as every product and every process requires energy to manufacture or to operate and thus leads to some environmental impact as stated by the second law of thermodynamics. Design solutions exist to improve overall efficiency in energy use, water use or raw material usage and waste generation.

Each of the individual designs may prove to be attractive to our outside partners in isolation and lead to further development or direct implementation. All of them will be valuable additions to the database in support of the overall USED tool. They might be the most cost effective means to reduce water usage in the community as whole.

### **2.3 Collaboration**

The success of the USED Centre is dependent on effective internal and external collaborations. Collaborations will flourish provided mutual trust develops and that all participants are benefiting.

Fortunately, within SOE, a collaborative culture is solidly in place between the faculty and between the faculty and staff. The collaboration occurs for both teaching and research. Thus, developing collaboration within SOE in design will be an extension of the current reality and will build on a collective commitment to design.

Collaboration between the faculty and other members of the university is also anticipated to be a simple extension of prevailing practices at Guelph. Currently, basic sciences, mathematics, computer programming and humanities courses in our curriculum are offered by sister departments at the university. The collaboration between these sister departments and SOE, to ensure that the needs of engineering students are met, has been quite effective. Research collaborations are quite extensive with Food Science, Land Resource Science, Chemistry, Environmental Biology, Human Kinetics and the Veterinary College. To this point, the university has been a source of a number of real-world capstone design projects for our students. Examples include controlling an odour problem in one of the veterinary buildings and designing a compost system for the animal waste generated on-site. It is anticipated that extending collaborative links to other campus units will be easy for the USED Centre. Professor John Livernois (Director - PhD program in Resource and Environmental Economics at Guelph) and Prof. James Taylor (Landscape Architecture) have agreed to participate.

As part of the writing of this proposal, collaboration with outside individuals has been active - Jim Gillies (P.Eng. - Blount), Bill Banks (P.Eng. - CG&S) and James Etienne (P.Eng. - City of Guelph). An advisory body will be established consisting of 8-12 members including Jim, Bill and James. The necessary support of the companies and organizations to complete Phase I is largely already in place.

Development of collaborative opportunities with other organizations are likely as the USED Centre proceeds. For example, the Elora Centre for Environmental Excellence (part of Natural Resources Canada's EnerGuide program) have synergistic interests - they will be surveying the energy efficiency of up to 12,000 Guelph homes over a 3 year period. This database of energy consumption and projected costs to reduce will be invaluable to the Centre. In exchange, the university will provide students to work on the survey teams and the types of inefficiencies observed in new and old homes will be excellent design challenges for undergraduate and graduate students alike.

C-DEN/RCCI has been established to develop a design network between institutions. The SOE has two particular advantages within C-DEN/RCCI. The SOE is within 100 km of five other universities that offer engineering: Toronto, Ryerson, McMaster, Waterloo and Western. Coupled with this central location is an established video conferencing link with McMaster and Waterloo. The second distinct advantage is that the proposed USED Centre is interdisciplinary providing valuable results to many engineering disciplines. The SOE is strongly committed to the C-DEN/RCCI initiative and was one of the first universities to establish its local C-DEN committee. Our local C-DEN committee includes all of the core design course instructors and the Environmental Design Engineering Chair will

be an active member.

## 2.4 Promotion

Environmental Design Engineering and the USED Centre will be promoted through:

- interactions with the local community
- a website
- interactions with other universities
- a public seminar series
- interactions with high schools
- design workshops
- the Federation of Canadian Municipalities

Initially, promotion efforts will focus on interactions with the local community. These interactions will include arranging visits and tours to communicate the goals of the USED Centre, the potential benefits to the community and for participating organizations. From this hub, promotion will flow outwards through the networks of the individual companies and organizations and through the communications of the Federation of Canadian Municipalities. The Federation of Canadian Municipalities (FCM) is already actively promoting environmental successes in one community to all of its members. ISO 9000 banner approach to promotion has been effective in building momentum and encouraging other companies to participate. It is believed that a similar concept with something indicating that a company, building or resident is a participant in the USED Centre would help promote the Centre and build momentum.

A website will be a key means of delivering information to participating organizations, members of the USED Centre, to other universities, to high schools and to the public in general.

Collaboration within the C-DEN/RCCI network will be the primary conduit for connection to our sister universities. The potential to establish an annual or biannual Design workshop between the design chairs would be attractive. These workshops will allow the exchange of success stories, the exchange of ideas regarding new approaches to the education and design objectives. Potentially an opportunity for an environmental design engineering competition.

A public seminar series on engineering design and environmental engineering design will be developed. The topics for these seminars would range from the design techniques of low flush toilets, of naturalized areas for maximum environmental benefits, of fuel cells for transportation. A combination of practicing engineers and academics would lead the seminars.

An important promotional activity will be connecting to the high school teacher and the high school student. Connecting to a high school student that is headed to an engineering undergraduate program will lead to an awareness of an engineer's role in environmental design engineering right from the outset. Additional students may be attracted to engineering if the false impression that engineering and environment are in conflict can be dispelled. An environmental design competition and providing resources for the high school teacher are two ways that will be used to make this connection.

To promote the activities and the success of the USED Centre and to assist in the evaluation of the Centre's performance, a workshop will be held in Year 4. Participation in the workshop by individuals from companies, communities and the educational sector (from across the country) will be encouraged.

## 2.5 Milestones and Performance Indicators

Milestones and Performance Indicators are provided in the following two sections. Numeric targets have been provided where possible for the performance indicators.

### 2.5.1 Milestones

#### Year 1

- Finalize membership of advisory body (8-12 members)
- Hire one faculty member and one technician
- Introduction of CAE in first year design course (3D graphics features/capabilities)
- Website up and running
- Phase IA initiated

#### Year 2

- Hire second new faculty member
- Modifications to Material Science, Numerical Methods & Fluid Mechanics courses
- Introduction of CAE in second year design course
- First offering of 4<sup>th</sup> year, integrating Engineering Design course
- First offering of a graduate course on Engineering Design Education
- Phase IB initiated

#### Year 3

- Hire third new faculty member
- Modifications to Thermodynamics & Heat Transfer courses
- Introduction of CAE in third year design course
- First offering of 4<sup>th</sup> year, creative Engineering Design course
- Phase IA (20% reduction in greenhouse gas emissions) complete

#### Year 4

- Phase IB (20% reduction in water usage) complete
- Workshop - Integrated Environmental Design Engineering for the Community
- Display Cases complete

#### Year 5

- Phase IIA (more sources), B (more environmental issues), & C (interrelationships) initiated
- Release of Version I of the Urban Systems Environmental Design tools

### 2.5.2 Quantitative and Qualitative Performance Indicators

The first set of performance indicators are ones in which reasonable numeric targets could be established.

- Number of first to third year student projects linked to local companies/organizations
  - 3 by Year 1
  - 10 by Year 5
- Number of Final Design (undergraduate) projects supportive of USED Centre
  - 6 by Year 1
  - 15 by Year 5
- Number of Design Graduate students active in USED Centre
  - 5 by Year 1
  - 20 by Year 5
- Number of local companies or organization endorsing the USED Centre  
*(Endorsement meaning: hiring students for design, providing undergraduate design projects, class room visits, plant tours, data, advisory body membership, graduate student projects or funding or...)*
  - reaches 20 by Year 2
  - reaches 40 by Year 5
- External Sponsorship for USED Centre
  - reaches \$50,000/a by Year 3
  - reaches \$100,000/a by Year 5
- Externally funding design research for USED Centre projects
  - reaches \$100,000/a by Year 3

For this second set of performance indicators, it was not felt that reasonable numeric targets should be established.

- Number of Designs implemented by collaborating companies
- Number of Designs implemented by collaborating companies that are dependent on the integrated capabilities
- Number of graduates active in Environmental Design Engineering and/or Design Engineering
- Number of Patents applied for and awarded
- Number of journal and conference papers
- Use of CAE tools for environmental improvements to outsider partner's products and processes
- Evidence that connections are being made to the high schools
- Public dissemination of success stories
- Education modules developed and adopted by sister institutions (C-DEN/RCCI)