出國報告（出國類別：參加國際會議）

美國生態工程學會
（AEES）2008 年年會

服務機關：行政院公共工程委員會

姓名職稱：塗技士佩菁

派赴國家：美國

出國期間：97.6.9~14

報告日期：97.08.08

目次

摘要

生態學主要針對於生態體系之研究，而工程學則是運用科學系統來解決問題。然而人類文明所造成對環境過度的發展，造成了環境與生態的破壞，由近期之颱風、豪雨所造成的災害，更讓我們體認了大自然反撲之力量。有鑒於此，我們需要有新的思維和解決途徑，來平衡生態系統與工程間的共生課題。生態工程的落實是邁向環境永續不可或缺的一環，而公共工程永續觀念必須同時考量經濟效率、環境保育、社會公義三面向，達到節能減碳、安全防災、環境保育等目標。

以國外經驗而言，美國生態工程學會（AEES，American Ecological Engineering Society)，1999 年首先由學者提案成立組織，於 2001 年成立，並由 15 個美國學校共同創立，且於每年 4-6 月，由不同大學輪流舉辦研討會。其宗旨在於為發展整合人類社會發展與自然環境之永續生態系統，透過加強教育及社區延伸服務，達到增進自然環境整體利益，擴展專業性及組織性、促使政府正視生態工程議題及鼓勵原創性研究。

本次出席會議名稱為「美國生態工程學會（AEES）2008 年年會」，於美國維吉尼亞理工大學舉辦 ，會議進行前 2 天，先分為 3 組針對「生態設計」、「河川復育設計」、「減輕濕地設計」主題進行討論並實地現勘當地河川，之後 2 天分為每天 3 場地，對「案例介紹」、「濕地設計」、「河川設計工具」、「都市系統」、「洪泛區域」、「地景設計」、「工程新知」等，約 77 篇論文發表。

本年度並舉辦學生河川設計比賽（約 7 組），透過學生對河川復育的概念與設計，以實際操作、製作模型，並進行實驗，選出於一定時間內對大水沖刷後，能保持最佳狀態的設計。AEES 過去投入生態工程的學術研究試圖結合實務應用，對學術界及工程界貢獻不遺餘力，特別是在生態復育及河川溪流、濕地生態工程方面，可作為國內於生態工程發展及實例工程之最佳借鏡。

壹、目的

人類對於經濟活動所產生的工程施作，往往只圖方便、實用，而未考量與整體生態環境之融合，其採用的工程施作方式進而危害生態體系的穩定平衡；為能改進國內生態工程所產生之困境與學習國外相關經驗，以瞭解美國生態工程相關技術研發、學術理論、實務發展及國際間交流，本次出席會議名稱為「美國生態工程學會（AEES）2008 年年會」。

其自 2001 年以來，為一每年定期舉辦之經常性會議，並由不同大學輪流舉辦，該學會成立目的在於為發展整合人類社會發展與自然環境之永續生態系統，透過加強教育及社區延伸服務達到增進自然環境整體利益，擴展專業性及組織性、促使政府正視生態工程議題及鼓勵原創性研究。

貳、行程

本年度會議於 97 年 6 月 9 日至 14 日在美國維吉尼亞理工大學（Virginia Tech .Blacksburg ,Virginia）舉行，主題名稱為「BEYOND WETLANDS：Engineering the Landscape」，與會人員約 140 餘人。

會議進行前 2 天，先分為 3 組針對「生態設計」、「河川復育設計」、「減輕濕地設計」主題進行討論並實地現勘當地河川，之後 2 天分為每天 3 場地，對「案例介紹」、「濕地設計」、「河川設計工具」、「都市系統」、「洪泛區域」、「地景設計」、「工程新知」等議題，約 77 篇論文發表。

最後一日為綜合討論，並贈送學生競賽組第一名獎品，由馬里蘭州立大學學生獲得。

會議行程表

日　　期	工　　作　　紀　　要
97 年 6 月 8 日	台北 → 美國
97 年 6 月 9 日	上午：報到、分組討論 （Ecological Design 101） （Process-Based Stream Restoration Design） （Mitigation Wetland Design） 下午：分組討論
97 年 6 月 10 日	上午：河川實地勘查 下午：分組討論
97 年 6 月 11 日	上午：報到、開幕致詞、論文發表 下午：論文發表
97 年 6 月 12 日	上午：論文發表 下午：論文發表 晚上：社交時間
97 年 6 月 13 日	上午：綜合討論 　　　贈送學生競賽組第一名獎品 下午：會議閉幕典禮
97 年 6 月 14 日	美國→ 台北

參、會議摘要

國際間有關生態工程較具知名度的組織共計有二單位，其一為國際生態工程學會（International Ecological Engineering Society, IEES），成立於 1993 年，地點位於瑞士，主要成員為生態學家，較屬學術性組織；另一組織為美國生態工程學會(American Ecological Engineering Society, AEES)，1999 年首先由學者提案成立組織，於 2001 年成立並召開第一次年會，迄今已召開第 8 屆年會，主要成員為工程師及學術人員。

本年度 AEES 年會主題名稱為「BEYOND WETLANDS：Engineering the Landscape」，與會人數共計約 140 餘人。本次會議所討論的主題內容豐富並具深度及廣度，在議題設計上將流域治理概念納入，另對溪流生態工程之復育提出多項專案報告，以下對「案例介紹」、「濕地設計」、「河川設計工具」、「都市系統」、「洪泛區域」、「地景設計」、「生態新知」等，摘要幾篇論文。

一、案例介紹：

在美國中西部，都市溪的更新：堪薩斯市的岩石小溪

溪流之恢復和穩定，在都市的環境裡是設計者的一項挑戰，其中相關物質環境的限制條件，例如過境權和現有基礎設施之影響；除此之外，經濟、文化，和政治問題，也關係著河川復育能否成功或者失敗。

在 2007 年，透過一份流域規劃之可行性研究性報告的訊息和建議，說明這條岩石小溪可作為高優先權地區的條件。來自諾爾 Roeland 運動途徑的岩石小溪，其一半英里的部分是最後一個保持有自然特點的岩石小溪的部分。

這條小溪並和公園設計結合，使得於都市中融合了城市娛樂、居住和趣味性。岩石小溪改進包括邊坡穩定、洪水管理，水質和棲息地改進。

這工程目的是提供洪水保護，透過將保護的一可持續設計並且更進一步提升地區的溪健康和棲息地。透過 HEC-RAS 模型用來獲得溪流的詳細基本分析，並了解水力是評價溪改進的穩定，對多種流動條件的傳達。

二、濕地設計：

土壤之調查，在地層學和地下水活動研究中，是一個集中時間的過程，那可能是極高花費和成品率之極限結果。而濕地通常在土壤特性非常不同的洪泛區底座，估計地下水貯存和活動之空間變化性。因此，濕地的減輕工程設計，決定了水文成功、降雨和地水表面之特性。而濕地設計重點在於理解都市形態學和土壤特性影響，怎樣安置現有的地下水活動，貯存和供應。

透過調查現有的土壤質地、密集氣孔和體積密度，能估計貯存量,活躍的樹生根的深度和橫向運動的地下水;當建造 forested 濕地時，是需要考慮的。並透過可行性調查能把這些屬性編入濕地設計。

三、河川設計工具

Agroecosystems 覆蓋全世界的土地廣大的地區，為眾所周知。在環境上，對於生態的設計來說，在這項研究過程中，建議 Agroecosystems 設計為多功能性、有潛能提供重要的生態系統服務，如水處理、營養的規章、生物多樣性保護，野生動物棲息地及社區。

設計過程從確定工地和風景開始，考慮到農場的關係，到臨近的特性和對整個流域之認知。在農場的風景架構和功能，然後能被表現特性和生物物理學的風景特徵上發展。

透過合併河邊的緩沖區，那樣的具體的風景特徵包括農業基體、樹籬、領域邊。最後，生態的設計應能透過提供基礎設施，鼓勵一個研究功能，使監控工程成功地保護環境，並且支持農場主生計。

肆、學生競賽第一名作品

Stroubles Creek Stream Restoration

2008 AEES Annual Meeting

Student Design Competition

University of Maryland Terps:

Jennifer Brundage

Jeff Price

Laura Schumann

Yin-Phan Tsang

Special Thanks to Pei-Ching, Tu

Our bench-scale design for restoring Stroubles Creek aimed to meet the four stated objectives:

1. Minimizing bank and bed erosion
2. Processing sediment load and flow through the reach
3. Maximizing nutrient cycling (i.e. dye retention)
4. Incorporating a variety of habitats for native plants and animals

Our design incorporated several main elements to meet these objectives, including:

- Meanders
- Log jam/ beaver dam
- A floodplain wetland
- Wetland plants
- Riffles and pools
- Braided channel
- Hummocky topography in the wetland

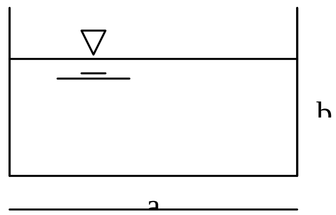
1. Design of stream channel cross-section to minimize erosion

Given: Strouble Creek has a base flow of 2.5 GPM (gallons per minute) and a storm event flow of 5 GPM with a 2% slope.

- We decided to design the stream channel bed dimensions based on the base flow. By doing this, the water is allowed to overflow to the floodplain wetland or other areas of depression nearby during the storm event flow. Floodplain interactions are especially important in this case to dissipating energy in the flow, settling out sediments and absorbing tracer dye.

- $Q_{base} = 2.5 \ GPM = 10 \ l/\min \cong 0.17 \ l/\sec = 0.00017 \, m^3/\sec$

- The channel as designed will be natural shaped and have protected or vegetated banks for minimizing erosion. Calculations were made to get a rough idea about the channel size and dimensions for our designed base flow. We calculated for the sake of simplicity, a rectangular cross-section and also used Manning's equation to estimate the stream channel cross-section for our reference.



$$\begin{cases} V = \frac{1}{n} R^{2/3} S^{1/2} \\ Q = VA \end{cases} \quad \text{with the} \quad Q = Q_{base}, R = \frac{A}{P} = \frac{a \times b}{a + 2b};$$

Both an example of a stream channel cross-section and the Manning equation and flow equation are displayed above. Since we would like our channel to be meander and be naturally protected, we used a roughness coefficient of n = 0.035 which is representative of a winding natural stream with a vegetated bed (from www.serc.arleton.edu). From this, we thus derived:

$$\Rightarrow \begin{cases} V = \frac{1}{0.035} \left(\frac{a \cdot b}{a + 2b} \right)^{2/3} \times (0.02)^{1/2} \\ 0.00017 = V \times (a \cdot b) \end{cases}$$

$$\Rightarrow 0.00017 = \left(\frac{1}{0.035} \left(\frac{a \cdot b}{a + 2b} \right)^{2/3} \times (0.02)^{1/2} \right) \cdot (a \cdot b)$$

- In order to solve for two unknowns, we used an MS Excel spreadsheet to experiment with different channel widths and water depth combinations. The final chosen size was:
  - Channel width $a \cong 0.06\ m = 6\ cm \cong 2.5\ inch$
  - Channel bank height $b \cong 0.025\ m = 2.5\ cm \cong 1\ inch$

- We thus use this for reference to create our stream channel in the model.

2. Processing sediment load and flow through the reach

Upon designing the stream channel we realized two major ways to reduce the erosive power of the stream flow. In our limited working space, we felt it would be important to:

1) reduce velocities using various structures such as pools and rock structures and;
2) reinforce high stress areas such as the outside banks with rock and large woody debris.

Several structures represent this attempt to reduce erosion within the streambed. A series of riffle and pool sequences were incorporated to slow velocities while adding a diversity of habitats. A very gradual meander was incorporated to the design to simulate in some way natural conditions, this also allowed room on our board for a backwater wetland where pooling could occur and sediments could settle out of the water column. We also built a mid-channel bar to split and slow flow by increasing surface area and roughness through the reach. Following the mid-channel bar, we created a log jam reinforced with clay material to create a pool where sediments could settle out as well as a nice island in the middle of the stream for habitat.
Although the flow turned out to be pretty slow, areas of potential high erosion were reinforced with a clay/rock mixture to limit erosion. All of the cutbanks had the clay mixture as well as other sensitive areas like the inlet flow from the hose and upstream side of the mid-channel bar responsible for splitting the flow.
We additionally felt the need to re-grade the stream banks from the heavily degraded current condition (vertical, heavily eroded and un-vegetated) to a more gradual slope to reduce the shear stress on the banks and allow for re-vegetation where the root structure will act to bind the soil. This slope was entirely approximated as our methods of carving were rough due the use of a utility knife in Styrofoam.

The channel was also lined with cobble stone in certain spots. The cobble simulates the streambed of a healthy stream with plenty of oxygenated flow through the hyporheic zone for invertebrates and spawning habitat for fish. This action also acts to slow flow while adding to the pool and riffle sequence. Although we would have liked to maximize floodplain interaction along the entire reach of the channel, we were limited in both time and ease to creating the only wetland and backwater to serve as our locations of floodplain interaction. Ideally, we would have liked to carve adjacent to the stream channel a very gradual sloping side-wall to act as a second stage flooded condition where sediments could be deposited and food and nutrients could be picked up and brought back into the stream. But as stated before, the Styrofoam made it difficult to be that precise.

3. Nutrient Attenuation

Our design maximizes nitrogen removal as consistent with the principles for nitrogen removal set forth by Dr. Margaret Palmer of the University of Maryland, Chesapeake Biological Laboratory:

- Increase flow path length (via meanders)
- Increase carbon sources (via woody debris and wetland creation with organic soil)
- Increase contact with the substrate (via widening of the channel and gently sloping the banks)

Most nitrogen in streams exists as nitrate because the stream water is generally well-oxygenated. Our log jam created a “dead water” area that fostered denitrification during base flows. Our design also diverts nitrate-rich stream water to the floodplain wetland where it can undergo denitrification under anaerobic conditions. The wetland also functions as a settling basin for stormwater and agricultural runoff laden with other nutrients such as phosphate, heavy metals, and other toxins to the wetland. Once this water is diverted to the wetland, excess phosphorus and toxins are sequestered and/or degraded by the harsh chemical conditions in the wetland soil. These substances are also taken up to a certain extent by the wetland plants, though this is not expected to be the primary removal pathway. During base flow our design diverted a small amount of stream water to the wetlands, and during the simulated storm flow this served as a major settling area for flood waters. We mimicked the absorptive, organic, wetland soil by lining our wetland with napkins and paper towels. Our wetland appeared to attenuate a significant amount of the dye carried during the simulated storm flow. The braided channel created by our island also enhanced nutrient removal by maximizing contact of stream water with the substrate.

4. Incorporating a variety of habitats

Our stream channel incorporates an engineered log jam, coarse woody debris, riffles, and pools to maximize habitat for aquatic invertebrates and fish. For example, baetid mayflies drift from riffles to pools and require both of these habitats in sequence. The gravel in our riffles and pools provides habitat for filter-feeding aquatic invertebrates and fish. The riffles and the coarse woody debris provide shelter from predators for a variety of aquatic invertebrates and a substrate for algae, the base of the food chain.

Our backwater wetland provided habitat for several native wetland species. We planted *Typha latifolia* (cattail), *Juncus effusus* (soft rush), *Murdania kaysak*, and maple and oak seedlings. These plants provided food and shelter for birds, ducks, and aquatic invertebrates. Our planting design incorporated the hummock and hollow topography typically found in stands of *J. effusus*, a tussock-forming species. These hummocks are valuable habitat for many species because they provide dry refugia from the wetter conditions in the hollows. Wading birds nest in hummocks, they are often colonized by plants which cannot tolerate fully anoxic conditions, and invertebrates also use them as refuge from water and predators.

Our design also incorporated two isolated wetlands. These were not designed to be hydrologically connected with the stream. They were designed with the knowledge that the real Stroubles Creek floodplain is underlain with clay and contains many wetlands which are hydrologically isolated from the stream. These were designed to provide additional habitat for wetland species.

伍、感想

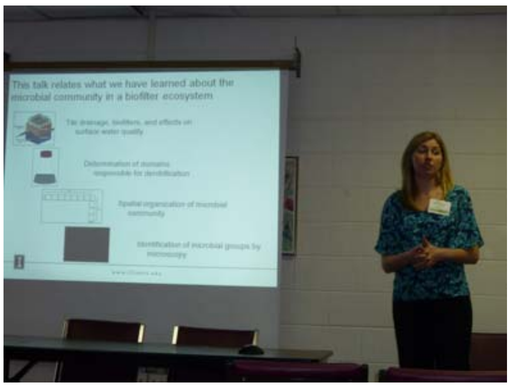
人類過度的開發行為對大自然造成的衝擊，包括環境資源過度開發與不當使用、造成污染源排放問題、稀有生物瀕臨絕種困境，以及部分忽略生態的公共工程等。這些過當的衝擊，將累積至大的能量，導致大自然的失調及反撲，也直接威脅人類的生存與生活。台灣在環境政策分析上運用生態工程，可追朔到1989年，1999年921地震後，直到2000年才正式應用於重建區大規模的土石流、崩塌地的整治，並逐漸推廣至對整體環境、生態與文化，在推動經濟與生態的發展上皆能兼顧，達到人與自然的永續和諧。

國內生態工法政策推動，因在技術研發及教育層面仍有待突破，所以常造成社會大眾認知落差，引發諸多阻力。在本會積極推動生態工程的成果下，在科技研發方面，辦理了多項研究案，有系統的從生態工程的材料選用、規劃設計、工程技術、檢核評估等技術面議題，到招標驗收、作業機制等制度面問題進行分析研究，各項成果皆提供各工程主辦機關參考應用，使得國內對生態工程有更進一步之認知。而參與國際性研討會更能了解國外在推動生態工程的努力，對環境之尊重，所展現之成果。

美國生態工程學會每年透過年會對生態工程的貢獻，將學術研究試圖結合實務應用，對學術界及工程界貢獻不遺餘力，研討會內容豐富並具深度及廣度，本次加入學生河川競賽，本人並參與其中一組學生設計，經實驗結果還獲得第一名成績；還有學者把他對地球生態的重視與熱愛，自創曲目獻唱給大家分享，為研討會增添了無比的歡樂與趣味。

附錄：活動照片


INFORMATION
AEES 2008
AEES Registration Upstairs
Colonial Hall
AEES 2008
Old Dominion


This talk relates what we have learned about the microbial community in a biofilter ecosystem