ENVIRONMENTAL CONSIDERATION IN FLOOD MITIGATION AND RIVER RESTORATION

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ABSTRACT

In last decades, Malaysia is subjected to rapid development and as a result severe flooding has occurred particularly in urban areas. Flood mitigation measures were taken to reduce the flood damage and channel improvement is mainly used for this purpose. In the past, consultant engineers normally proposed a wider and deeper rectangular concrete river channel to mitigate the flood. This is because of the limited available river reserve and possibly the lack of environmental awareness. The consequences of replacing the natural river channel with a concrete channel are reduction of aesthetic and recreational values of rivers and increased physical degradation including damaging the river ecosystem. Recently, there is a great emphasis to consider the environmental impact in canalizing rivers. In this study, the Malaysian experience in urban river restoration is highlighted with special emphasis on environmentally friendly materials installed for flood mitigation purposes.

Keywords: *Restoration, Urban Rivers, Channel Improvement, Flood, Environment*

1. INTRODUCTION

Due to various human activities, radical changes to rivers and streams occurred in the last century. On the contrary, the environmental awareness has grown and led to pressures on river managers to repair some of the past damages and restore rivers to previous condition so that they become more sustainable and ecologically and aesthetically desired condition. The modification of rivers in developed countries were intensive particularly in the last 50 years where the modification included flood defense projects, development of flood plain and changing land use within the catchment. The implemented works on rivers and their environmental consequences are summarized in Table1.

Table 1: Types of River Developments and Their Environmental Consequences

No.	Type of Development	Environmental consequences
1	River improvements such as extensive straightening and deepening of river channels for flood mitigation projects	Damaging wildlife habitats, reducing the value of fishers, damaging or removing the aesthetic value of river landscapes
2	Major loss of flood plain wetlands through intensive agricultural use and urbanization projects	Polluting river water, destroying wildlife habitats and reducing the ability of floodplains to function as water and sediment storage
3	Intervention with the river water course through construction of hydraulic structures such as dams, barrages regulators and bridges for developmental and flood alleviation purposes	Negative impacting on the natural river processes.

River restoration can be defined as implemented actions to rivers and their basins which are subjected to severe pollution and damage to their natural habitats in order to return them to the original conditions before damage. Restoration activities as described by Grant (2008) include increasing flows to dilute water contaminants, removing levees to promote channel storage of water and sediment, adding gravel to river to increase hyporheic flow and controlling invasive species to improve native ecosystem. The above activities illustrate the range of technical disciplines required for river restoration such as engineering, hydrology, geomorphology and ecology. Figure 1 shows the conceptual framework for restoration (Grant, 2008).

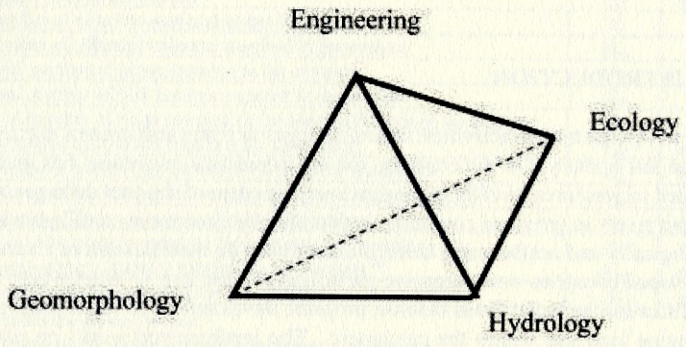

Figure 1: Conceptual frame work for river restoration (Grant, 2008).

River restoration brings the following benefits:

1. Nature conservation - through the protection of wetland wildlife, not just plants and animals within the channel itself but from the recreation of the rich mosaic of floodplain habitats.
2. Improved water quality - through recreation of floodplains which intercept pollutants and act as a natural settling area for flood-borne sediments.
3. Flood defense - through the interception of storm run-off and the provision of additional flood storage areas which can help to prevent flood damage in other areas.
4. Fisheries - through the recreation of habitats and conditions suitable for a diversity of fish species.
5. Recreation - through improvements in river landscapes and river-based activities.

There are two main approaches used for river restoration:

a. Natural recovery where appropriate streams and rivers are allowed to recreate their own natural course and flooding regime.
b. Active restoration where intervention is required to modify rivers which are too badly damaged or have too little sediment and water power to repair themselves.

It is important to emphasize the concept of connectivity between the river channel and its floodplain. This is where the greatest benefits will come through the restoration of natural river processes and functions.

River natural recovery process after restoration depends on the river condition (how bad is the damage) and it changes from river to river. The time required for river recovery is several years for rivers with minor damage and it may take a much longer time for badly damaged rivers.

In this study, the Malaysian experience in river restoration is presented with special emphasis on the experience of improving rivers for flood mitigation and also taking into consideration the environmental, river ecological system and aesthetic value.

2. TYPES OF REVETMENT SYSTEMS FOR RIVER RESTORATION

Escarameia (1998) categorised the revetment systems which are used for river rehabilitation and restoration into three main types namely; bioengineering (vegetation), structural and bio-technical engineering. Bioengineering revetment system is used mainly for rehabilitation and restoration of rivers. The challenge in bioengineering is to protect the bank from erosion until the vegetation becomes established and it takes more than a year. Allen (1978) discussed five mechanisms through which vegetation can aid erosion control: reinforce soil through roots; dampen waves or dissipate wave energy; intercept water; enhance water infiltration; and deplete soil water by uptake and transpiration. However, from the engineering perspective, the use of vegetation alone on streambanks is not always ideal. Excessive foliage can lead to the reduction in channel capacity and a greater flood potential upstream. Trees planted on certain parts of levees may have roots undermining the levee stability (USACE, 1999). Coppin and Richards (1990) have analyzed engineering functions of vegetation and determined that its effects are both adverse and beneficial, depending on the circumstances. Therefore, it is important not to solve a streambank problem by employing a single measure. The structural revetment system was widely used in 1950 to 1980 (Bakker, et al., 2004). Various protective structural linings have been used to overcome the erosion problems. These hard-armoring methods such as stone riprap, concrete pavement, rock gabions, concrete or aluminum, sack revetments and asphalt mixes reinforced streambank shear strength (Keown and Oswalt, 1984). Many governmental agencies favored stone or concrete riprap because over time, a high degree of precision and confidence in construction has developed from research and analysis. In engineering viewpoints, these methods have been successful for their immediate protection. Combining different bioengineering techniques even with structural components is actually more effective than using any specific one alone (Henderson, 1986). Biotechnical is a technique for bank stabilization that incorporates the use of vegetation and engineering structures to increase slope stability (Ming and Karen, 2002). The vegetation increases the soil strength through their root structure while the bio-engineered structure provides additional support. Moreover, it rehabilitates the river and improves the ecological life. However, it can be used as an effective solution for restoration projects. Figure 2 shows various types of biotechnical materials available in the market.

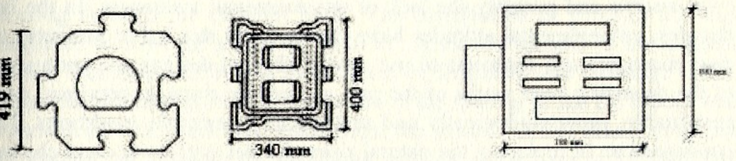

Figure 2: Selected types of bio-technical engineering blocks.

3. APPLICATION OF RIVER RESTORATION MEASURES: THE INTERNATIONAL EXPERIENCE

In the last two decades, European Union countries started to focus on restoration of rivers and EU has funded a number of isolated river restoration projects. However, to increase the benefits and to disseminate knowledge and experience on river restoration gained within Europe, a center called European Centre for River Restoration (ECRR) was established in 1995.

Pollution is the main contribution to river damages in European Union. Even though intensified wastewater treatment has significantly reduced the concentration of organic matter and phosphorus, the nitrogen concentration in European rivers has been increasing causing eutrophication in the marine environment. The main reason for this is the intensification of European agriculture causing increased loading of nitrogen due to increased use of fertilisers and manure. As a consequence, both the water quality and river habitat quality have been seriously degraded in numerous European rivers throughout this century. Physical deterioration of rivers and their floodplains is common all over Europe. In Belgium, Denmark, England and Wales less than 20% of the rivers are still in the natural physical state. Engineering works in European rivers have significantly changed water retention capacity resulting in downstream flooding. The uniformity of channelised and deepened rivers provides poor conditions for aquatic life, whereas a restored watercourse provides more and better habitats for flora and fauna.

The more diverse the physical and environmental conditions, the higher the biodiversity. Action program for biodiversity in Europe is given high priority and nature restoration has been identified as one of the measures to maintain and improve biodiversity. An example for rivers restored in Europe is River Rhine, River Meuse, River Skjern and Lubrzonka River. Weller (1998) highlighted the effect of good management of flood on river restoration and particularly on reducing flooding hazards and preserving the biodiversity in the river environment. Wetlands are essential part of a functional river system and can help in improving the river water quality affected by sediments. Diamond et al. (2001) suggested improvement objectives for river reaches good ecological potential. They apply the water framework directive to three rivers in the United Kingdom (UK). The directive included the definition of heavily modified water bodies, development of a dynamic classification system for hydromorphology and for development of physical quality objectives. Menke and Cals (2002) stated a rehabilitation vision to River Dinkel (one of the tributaries of River Rhine) which is located east of the Netherlands. The river problems are pollution, unnatural discharges, and habitats structures (e.g. weirs). The vision included measures to improve water quality, remeandering of brooks and flood protection.

Arnaud-Fassetta and Fort (2008) proposed restoration of River Aude, South of France. The native riparian vegetation is allowed to remain dominant, thus enhancing habitat diversity and acting as a sediment trap especially along abandoned channels. Gilligan (2008) reported that 40% of the river bodies in Ireland are designated either at risk or probably at risk of failing good ecological status. Half of the above reported cases are due to channelisation and flood relief structures. Menke and Nijland (2008) proposed relocation of dyke for certain stretches along River Rhine in Germany and Netherlands. The relocation include reconnected floodplain area to create a good quality riverine habitats and improve the ecological network along the river.

Development pressures have changed river systems throughout the United States of America. Traditional engineering concepts have been applied to problems of flood control, irrigation, highway construction, and general land management conflicts. This approach has failed to incorporate natural river geometry, channel behavior, riparian function as well as associated aesthetic and financial value. The river and stream alterations have resulted in adverse habitat changes for many fish and wildlife species that have contributed to major declines in native fish populations and problems of bankfull information is lacking for most rivers. Data on the discharges at channel capacity or on the gauge height of the bankfull condition are not published or even determined in a systematic manner despite their importance to planners, environmentalists and everyone interested in floods and flooding. Examples of the river restored in USA are Little Tennessee River and Mississippi River (Shuler, 2008).

In Australia, the Cooperative Research Centre (CRC) for Catchment Hydrology's River Restoration research program aims to provide stream managers with tools, and with understanding of stream processes, that will lead to more effective expenditure on restoration, and ultimately, healthier streams. River rehabilitation for Australian streams is planned and one example of this plan is the restoration work on Latrobe River in South East Australia (Rutherfurd, 2001). Rutherfurd (2008) reported the results on modeling the physical and ecological response of Creighton and Castle Creeks system to intervention by presenting the variation of bed levels with the proposed type of solution.

In Japan, the concept of potential nature in riverine environment is introduced by extending the concept of today's potential natural vegetation in ecology. Degradation of the quality of nature in riverine environment in modern Japan is a result of the impact of human and modern technology and industrialization. Guideline for riverine environment in Japan can be summarized as 1) natural disturbance regime, 2) continuity in a watershed, and 3) diversity of morphology. This concept is applied for river restoration in Japan to satisfy essential requirements of environmental ethics. Nakamura (2008) reported that in Japan, 23.5% of the river banks are artificial and 2675 dams (with the total height of more than 15 m) have been constructed and the number of restoration projects is 28,000. The Asian River Restoration Network was established in November 2006 to support the exchange of information relating to environmental restoration of rivers and watersheds within Asian countries.

4. FLOOD MITIGATION AND RIVER RESTORATION IN MALAYSIA

In tropical countries like Malaysia where the average annual rainfall is more than 2500 mm, flooding is considered an inevitable problem particularly in urbanized rivers. Normally, flood mitigation measures are implemented to reduce flood damage in flood plain for urbanized areas. Channel improvement is mainly used for this purpose. The consultant engineers would normally propose a rectangular concrete section to improve the channel of flooded rivers. So, it often happens that the undersized natural channel section of a river is changed to a wider and deeper rectangular concrete channel in order to increase the hydraulic capacity and reduce flood hazard on public. This solution is usually proposed by the design engineers because of the limited available river reserve and possibly the lack of environmental awareness. In the last decades, environmental attitudes have changed and this led to pressures on river managers and engineers to use natural channel designs and undo some of the damaging river works of the past and restore rivers to previous, more sustainable, more ecologically and aesthetically desirable conditions. The consequences of replacing the natural river channel with a concrete channel in flood mitigation projects are reduction of aesthetic and recreational values of rivers and increasing the physical degradation. On the contrary, natural channel designs will enhance the river biodiversity and proliferation of flora and fauna habitats. Integration of natural channel design with the river restoration requirements needs knowledge on river physical and biological processes, river aesthetic value, hydraulic and sediment transport calculations, hydraulic structures, fish habitat improvement designs, stream-bank stabilization techniques, and riparian area improvement and function. This confirms the concept highlighted by Grant (2008) as shown in Figure 1.

Scouring is the main problem in natural channel design of rivers. Scouring is considered a destroyer and killer of streams. Scouring can be reduced and its effect minimized by careful streambank protection. To reduce the maintenance work for scoured banks of rivers and streams, effort is made to produce environmentally friendly materials (biotechnical) which can be used as a revetment for river banks protection for flood mitigation projects. In the last two decades, bio-technical block systems are patented, produced and used in the United States of America (USA), Europe and Australia. Some of these systems have also been used in Malaysia. There are many advantages of using these revetment materials. These advantages are maintaining dimensions of the river channel, increasing hydraulic capacity to pass the designed flood, reducing scouring, increasing natural aesthetic value to the river and improving biodiversity and ecological life in the river.

Only three case studies in Malaysia will be presented. In order to avoid any promotion to the mentioned materials and also to uphold the rights of the production companies, their products names will not be mentioned in this study and a product code will be used.

Case study 1 presents the channel design of Sungai Klang at Jalan Dang Wangi, Kuala Lumpur. Product D2 was used as an environmentally friendly revetment material to protect riverbank which was experiencing massive natural scouring. The scouring occurred due to changes in current flow and seepage effect. Since Sungai Klang's riverbank consists of silty and sandy sub-soils, it cannot respond quickly to avoid relatively high pressure gradient due to discharges entering through the channel bank. The installation of product D2 was completed in 1994 for a total of 3,000 m^2. After two months of installation, the site was surveyed by the Department of Irrigation and Drainage (DID, Kuala Lumpur) and growth of vegetation in the spacing of the D2 blocks was observed. Over 8 years after installation, the product is still functioning and not washed out although the maximum velocity at the river is 5.1 m/s. The river section is designed to carry a discharge of 431 m^3/s and the maximum water depth of this section is 3.5 m. It had recorded in the last 7 years between 1994 and 2001, the maximum water depth during flash flood in Kuala Lumpur was 4.9 m. The maximum flow velocity was 5.1 m/s in year 2000 which contributed to the maximum discharge of 627 m^3/s. During flash floods, the water from seepage and surface runoff also contributed to the increment of discharges, water depth and velocity of flow. The revetment system has functioned well and has protected the bank from high velocity flow.

Case study 2 was a flood mitigation project where the channel of Sungai Kepayang at Seremban, Negeri Sembilan was improved using environmentally friendly revetment type B2. Installation of Product B2 was completed in 1999 and the total application of product B2 as a riverbank revetments material in Sungai Kepayang was 2500 m^2. After three years, the same site was surveyed and inspected by Department of Irrigation and Drainage, Negeri Sembilan. They found that there was a growth of vegetation between the revetment spacing of the product B2. Monitoring showed that the maximum velocity of the flow during flood time was 3.6 m/s while the design velocity was 3 m/s.

Case study 3 includes Sungai Anak Air Garam in Seremban, Negeri Sembilan and product L3 is used as revetment system for bank protection. This riverbank is located between the residential areas, petrol Kiosks and shop houses and work is completed in 1999. The bank area protected by L3 revetment system is 2800 m^2. Vegetation is found to be growing on the revetment.

5. DISCUSSION

The increasing importance of river restoration has presented a new challenge to river managers for better effective practices to conserve river ecosystems. Recently, solutions to mitigate flood and control bank erosion in Malaysia are proposed to comply with river restoration measures. The undersized natural river channel has been changed to a wider and deeper rectangular concrete section in flood mitigation as shown in Figure 1.

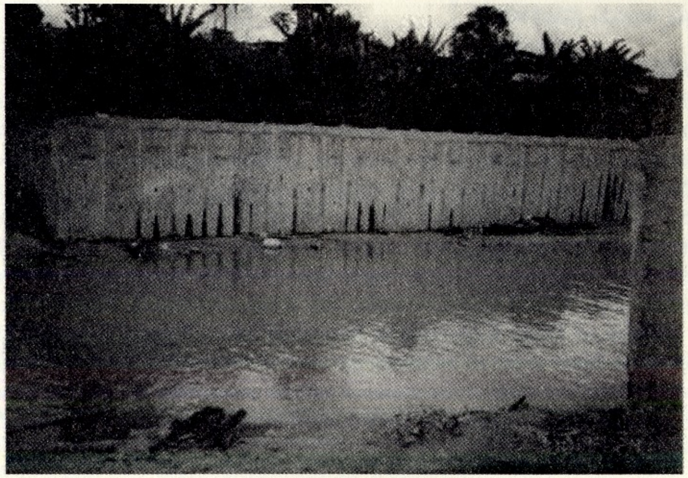

Figure 3: A stretch of river Kepayang in Negeri Sembilan, Malaysia with concrete channel.

According to Williams (2001) the river engineering works are the main cause of environmental degradation for ecosystems of rivers and estuaries and loss of biodiversity. Concrete river channel will function as a carrying drain only and the self purification process for improving river water quality which normally happens in natural river and stream channels is severely affected or ceased.

The main obstacle facing river managers and design engineers in their effort to restore and rehabilitate rivers in Malaysia is the very high cost of land acquisition particularly in the town area. However, most of the rectangular concrete river channels are located in towns. Jasperse and Wind (2002) highlighted that the main problem for river restoration projects in Netherlands is land acquisition.

Native vegetation schemes are increasingly being used around the world with the trapezoidal earth section in flood mitigation schemes and also to manage stream scouring. Beside its environmental advantages, the vegetation increases bank sheer strength due to root reinforcement and this will stabilize the sloping river banks (Abernethy and Rutherfurd, 2000). Since river restoration aims to return natural and environmental values to river and stream channels, natural materials are used for this purpose. Figures 2 and 3 show bank protection using natural materials.

In Malaysia, most of the rivers with steep longitudinal gradient are subjected to scouring. Normally, scouring resulted from high velocity of flow in these rivers during floods. Figure 4 shows scoured river bank. To reduce the effect of erosion, several types of bio-technical systems (environmentally friendly materials) have been used in flood mitigation projects for two main objectives. The first objective is to protect the river banks from erosion while the second objective is to bring back the original condition of the river channel. The vegetation can grow on the river bank after using the revetment system and then the river channel appears exactly like a natural channel. Figure 7 shows the channel of River Kepayang at Seremban town, Negeri Sembilan after restoration. Many types of materials are used in Malaysia as river revetments. Table 2 shows the code of the material and the percentage of spacing in each one and the rate of vegetation growth after construction in river restoration projects.

Figure 4: Installing stakes to protect the river bank form erosion.

Figure 5: A case of bank protection using natural vegetal cover.

Figure 6: Scouring of river bank.

Figure 7: River Kepayang in Malaysia after restoration.

From river restoration point of view, vegetation growth is considered the main category to assess the environmental performance of the installed materials for river bank protection. For the studied rivers in Malaysia, almost all the installed revetment systems show potential ability to protect river banks. The growth of the vegetation eventually extends over the top of the revetment materials and provides a complete vegetal cover to the bank which contributes to the stability as well as ecological and aesthetic value of the area which are in line with the river restoration concept.

Table 2: Evaluation for Revetment Systems Used for River Restoration in Malaysia

Product Code	Spacing Allowed (%) per m^2	Vegetation Growth Rating
A1-A2	6.5	Slow
B1	18	Moderate
B2	6.5	Slow
B3-B4	18	Moderate
B5	20	Fast
C1	15	Moderate
D1-D2	12	Moderate
E1-E4	5	Slow
G1-G4	>30	Fast
H1-H5	>30	Fast
J1	20	Fast
K1-K6	< 10	Slow
L1-L4	< 10	Fast

6. CONCLUSIONS

The ultimate goal of river restoration is the return of the pre-disturbance state of rivers and recently there is increasing scientific evidence which demonstrates that the major river engineering works have been a main cause of environmental degradation of the river ecosystems and a significant factor in the loss of biodiversity in river environment. In Malaysia, the river managers and engineers directed their effort towards the restoration of rivers. Increasingly, river restoration concept is being used as a guide in flood mitigation works and particularly for channel improvement. The new practice is to use environmental friendly revetment systems instead of using deep and wide rectangular concrete channel. Land acquisition is considered an economical constraint which affects the restoration and rehabilitation of rivers in the town areas. Environmental friendly revetment systems which were installed in three rivers showed the growth of the natural habitat at the river banks and flood plains. The restoration of rivers in Malaysia is considered to be in its early stage and more work need to be done to save the rivers form environmental degradation.

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