Drainage Services Department Practice Note No. 1/2005

Guidelines on Environmental Considerations for River Channel Design

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1. SCOPE

This Practice Note (PN) presents the essential environmental considerations that should be taken into account and incorporated wherever practicable, in the design of river channels. It was prepared by a working group, chaired by the Chief Engineer of our Mainland North Division and comprised representatives from the Agriculture, Fisheries and Conservation Department (AFCD), Environmental Protection Department (EPD), Highways Department (HyD), Civil Engineering and Development Department (CEDD), Leisure and Cultural Services Department (LCSD) and other Divisions of this Department.

2. INTRODUCTION

In recent years, Drainage Services Department (DSD) has been striving to incorporate as much as practicable ecological considerations and features in its design of river channels and floodways. Examples include the use of grassed cellular concrete paving and geo-fabric reinforced grass lining for river embankments and bed; creating steps, curves and aquatic planting ponds/bays in the channel; creating marshland and ecological reed beds alongside the channel, etc. In some cases, green groups were involved and consulted in the design on ecological aspects. Despite all these efforts, the call for more ecologically friendly river channel design and the need to design a channel matching with the adjacent environment are ever increasing.

To address the need for more environmentally friendly design and be in line with the new measures being put in place by Government to strengthen the protection of natural rivers and streams in Hong Kong, these guidelines are prepared by an inter-departmental working group to provide a design framework for a project proponent to go through and base upon, with a view to producing a river channel design as environmentally friendly as possible. In producing the document, the working group has collected and reviewed local as well as overseas experience (where available) in the design of river channels, prior to formulation of the guidelines.

It should be pointed out that these guidelines only cover the essential environmental aspects that should be taken into consideration. Other design aspects such as hydraulic performance, maintenance provisions, etc. should still comply with the requirements/standards set out in the Stormwater Drainage Manual (SDM) and other relevant technical circulars and practice notes.

It is however recognized that, due to various practical constraints such as land availability and characteristics, public objections, programme requirements, efficiency and effectiveness of the engineering performance, embankment stability, etc, it may not be possible to strictly follow and incorporate the most desirable design approach and environmental measures. Neither will it be possible to have a standard environmentally friendly design for a project proponent to follow suit. The objective is for the project proponent to apply the recommended design framework in the project planning and design stages, by detailed appraisals, assessment, comparison and careful balancing to achieve a design and/or combination of designs which is environmentally friendly as well as effective in engineering performance.

3. ECOLOGICAL IMPACTS DUE TO RIVER TRAINING WORKS

River channelization is carried out for the purposes of drainage improvement, flood prevention, reduction of bank erosion or river realignment to blend in with future development. It involves engineering works, such as bank protection, widening, deepening and realignment of original river channel, that will cause direct and indirect impacts on the river and riparian ecosystems.

3.1 DIRECT IMPACTS

Dredging and excavation for deepening and widening of a river will respectively destroy benthic and riparian habitats during the construction phase. This would cause significant impact even if the habitats are properly reinstated after construction.

Depending on the design of the project, river channelization has significant impact on river ecosystem due to physical changes in channel morphology, bottom substrates, river margins (the area immediately adjacent to the river flow), bank structure as well as hydrological regime. The impacts are described in the following paragraphs.

The use of artificial non-vegetative smooth lining, such as concrete on the river bed and embankment, will cause a total loss of riverine habitats (including pools, riffles, aquatic, benthic and riparian habitats) and the ecological impacts will be severe. The faster water current and lowered water level after river channelization, particularly those provided with dry weather flow channel, may also create unfavorable conditions for the aquatic organisms to recolonise in the new channel.

River realignment/straightening will cause sections of meanders to be cut off from constant water supply, resulting in loss of riverine habitats. Special consideration wherever possible and practicable should be given in the design to minimize such ecological impact.

Construction of embankment along the river to replace natural bank and margin with steep artificial channel bank would affect the ecological and hydrological connectivity between the aquatic and adjacent riparian and terrestrial habitats (e.g. amphibians, which rely on both aquatic and terrestrial habitats, may not be able to complete their life-cycle; mammals and reptiles may not be able to get to the stream for water).

Installation of dams and/or weirs would fragment the river channel longitudinally and obstruct the free passage of fish and other aquatic organisms between upstream and downstream.

Channel widening may damage riparian vegetation which would subsequently reduce shading, increase water temperature and reduce organic input to the river. All these changes will have subsequent ecological impacts on the aquatic communities.

Too frequent dredging for desilting or weed cutting in a river channel will cause ecological impact and arrest natural recovery of aquatic and riparian organisms. These operations should be planned carefully in terms of frequency, phasing and timing in order to minimize environmental impacts on the river channels.

3.2 INDIRECT IMPACTS

Channelization works would affect downstream in terms of water quality (e.g. increase in sedimentation) and flow regime (e.g. increase in water current and peak flow). These hydrological changes would cause ecological impacts subsequently.

Channelization works for land drainage may also affect riparian vegetation and adjacent wetland habitat due to the drawing down of groundwater table. Where water tables are lowered or surface waters drained, the aquatic organisms and associated communities (e.g. wetland birds) would gradually be replaced by terrestrial communities.

4. EXISTING GUIDELINES ON RIVER CHANNEL PROJECTS

It is the Government's policy that every river channel construction project has to go through an environmental review and where necessary an environmental impact assessment during the planning and design stages to ensure that the proposed works will have minimal impacts on the environment. In this regard, relevant guidelines and circulars to give general requirements and guidance on environmental issues have been established for the project officers to follow in the planning and design of a river channel project. The following is a brief description of the current legislation, guidelines and circulars which govern the design of the river channel projects.

4.1 ENVIRONMENTAL IMPACT ASSESSMENT ORDINANCE

The Environmental Impact Assessment Ordinance (EIAO) (CAP 499) was enacted in February 1997 and came into operation on 1 April 1998. The purpose of the EIAO is to avoid, minimize and/or compensate adverse impacts on the environment arising from projects classified as "Designated Projects" under Schedules 2 or 3 of the Ordinance, through the application of Environmental Impact Assessment (EIA) process and Environmental Permit (EP) system. The air, noise, dust, water and mud disposal, ecological, visual and landscape aspects should also be considered.

If training and diversion works of drainage channels or rivers involve a channel width of more than 100 m or discharges into an area which is less than 300 m from the nearest boundary of any of the following existing or planned area/site:

a. site of special scientific interest;
b. site of cultural heritage;
c. marine park or marine reserve;
d. fish culture zone;
e. wild animal protection area;
f. coastal protection area; or
g. conservation area;

the project is classified as a Designated Project and an EP is required.

To further elaborate on the requirement of how to prepare an EIA report, EPD has provided technical guidance to the EIA process in the "Technical Memorandum on Environmental Impact Assessment Process". Project officers should follow the Technical Memorandum which can be viewed in EPD's website.

4.2 PROJECT ADMINISTRATION HANDBOOK

Project Administration Handbook (PAH) provides an overall general guidance for project officers to follow during the planning, design and construction of a public works project. It has stipulated the general requirements on the environmental aspect that the project officers need to observe when implementing a project.

During the project planning stage, the project officers need to keep close contact with EPD and AFCD (PAH Chapter 1, Cl. 1.5), and when appropriate, to consult the Advisory Council on the Environment if *"the project is environmentally and/or ecologically sensitive"*. (PAH Chapter 1, Cl. 1.6.2) When preparing the Technical Feasibility Statement, information on environmental considerations should be provided including statements showing that *"the project office should identify environmentally sensitive areas and try to avoid impacts to the environment"*, and category of the project and requirement under the EIAO. (PAH Chapter 1 Cl. 1.4.2 and 3.1.2 (d))

During the design stage of the project, PAH states that "*all plans for engineering projects must pay full regard to environmental factors including noise or other nuisance, pollution of ground, water or air, effects on fauna and flora, and landscape and visual effects (both during and after construction), with a view to ensuring maximum mitigation of unavoidable harm, and securing signification improvements in the environment where possible and affordable.*" (PAH Chapter 4 Cl. 4.13)

4.3 STORMWATER DRAINAGE MANUAL

The Stormwater Drainage Manual (SDM), which more specifically refers to the river channel projects, also stipulates that "*all the drainage works should be designed to blend in with the environment.*" (SDM Cl. 3.4.1) and "*In addition to the air, noise, dust and water aspects which are usually considered for most civil engineering works, issues such as... the impact of large-scale drainage works on the ecology of the surrounding areas should also require detailed assessment. Mitigating measures such as wetland compensation should be devised accordingly.*" (SDM Cl. 3.4.2)

4.4 TECHNICAL CIRCULARS

Standard as well as enhanced procedures and principles on environmental considerations of river channel projects have already been stipulated in a number of Technical Circulars. The most relevant ones include:

a. ETWB TCW No. 5/2005 – Protection of Natural Streams/Rivers from Adverse Impacts Arising from Construction Works

   The circular, newly issued in March 2005, aims to provide a more comprehensive administrative framework to better protect natural streams/rivers from the impacts of government works projects and private developments. It formalizes and enhances the existing measures for the protection of natural streams/rivers, and provides guidance for the departments concerned to minimize or, if possible, avoid impacts of works projects on natural streams/rivers during the planning, design and construction stages.

b. DSD TC No. 2/2004 – Protection of Natural Rivers and Streams from Adverse Impacts Arising from Construction Works

This circular is the updated version and expansion of the previous DSD TC 4/2002. It provides guidelines for the planning and execution of construction works and for the vetting of public and private development proposals that affect natural rivers and streams particularly those classified as ecologically important. The circular also specifies that *"Construction works should be restrained to minimize possible disturbance to the ecosystem of these rivers and streams... they should be carried out in an environmentally responsible manner and with appropriate precautionary measures to minimize any adverse impact caused to these rivers and streams."*

c. ETWB TCW No. 13/2003 – Guidelines and Procedures for Environmental Impact Assessment of Government Projects and Proposals

This circular sets out the guidelines and procedures for EIA of government projects and proposals, including those not covered by the EIAO.

The circular also specifies that *"projects that do not fall within the requirements of EIAO are classified as non-designated projects, which however may also have a potential to cause adverse impacts to the environment... proponents, including their consultants and contractors, should give sufficient regards to protecting the environment during design, construction and operation particularly for activities with possible impacts on sensitive areas of the environment. The relevant guidelines issued by EPD should be observed so that all necessary precautionary measures could be made to avoid potential environmental damage and, if avoidance is not practicable, to minimize adverse environmental effects."*

d. WBTC No. 4/1997 – Guidelines for implementing off-site ecological mitigation measures

This circular sets out guidelines for the implementation of the Government's policy on off-site ecological mitigation measures which, in brief, requires that where such a measure is required, it would be provided to the extent that it is practicable, on a like-for-like basis and within the boundaries of Hong Kong.

e. Other Technical Circulars on Landscape and Planting

Technical documents which may provide useful reference on landscape aspect in association with drainage improvement works of river/stream include:

- ETWB TCW No. 36/2004 "The Advisory Committee on the Appearance of Bridges and Associated Structures (ACABAS)",
- ETWB TCW No. 29/2004 "Registration of Old and Valuable Trees, and Guidelines for their Preservation",
- ETWB TCW No. 11/2004 "Cyber Manual for Greening",
- ETWB TCW No. 2/2004 "Maintenance of Vegetation and Hard Landscape Features",
- ETWB TCW No. 34/2003 "Community Involvement in Greening Works",
- ETWB TCW No. 14/2002 "Management and Maintenance of Natural Vegetation and Landscaping Works and Tree Preservation",
- WBTC No. 7/2002 "Tree Planting in Public Works",
- WBTC No. 17/2000 "Improvement to the Appearance of Slopes"
- WBTC No. 25/1993 "Control of Visual Impact of slopes"
- WBTC No. 25/1992 "Allocation of Spaces for Urban Street Tree"

4.5 OTHER RELEVANT DOCUMENTS

To facilitate the project officers to design the river channel in a more environmentally friendly manner as well as to ensure the engineering performance, there are also several relevant documents produced by DSD and other departments which the project officers can make reference to:

a. Aesthetic, Environmental and Ecological Considerations in the Design of Drainage Channels by R&D Section, Land Drainage Division, DSD - October 2003

The report summarizes the review of the recent major drainage improvement projects in Hong Kong and recommends good practice for drainage channel design with due consideration on the aesthetic, environmental and ecological aspects.

b. DSD Practice Note No. 3/2003

This Practice Note sets out the critical issues to be considered in the design of open channels accommodating supercritical flows, in particular when the occurrence of hydraulic jump is anticipated. It also stipulates the requirements for linings and bedding against uplift forces and aggravated erosion under the effects of supercritical flows and higher velocities in localized areas of the channels.

c. Guidance Note for Incorporation of Environmental Features into Drainage and Flood Protection Works for Visual Enhancement – June 2001

This guidance note was prepared by the Drainage Projects Division of DSD. It summarizes the guidelines for good practice and lists out the possible environmental features of drainage and flood protection works for visual enhancement and improvement of the ecosystem.

d. Examples of Environmentally Friendly Drainage Channel Designs Arising from Environmental Impact Assessments by EPD, DSD, AFCD & CEDD (then TDD) - May 1999

The document was produced as a result of discussions at the EIA Sub-committee of the Advisory Council on the Environment on the environmental design of drainage channels. It summarizes the environmentally friendly design measures recommended in the five EIA studies on the major drainage channels in the Northern and North-western New Territories, including Ng Tung River, Sheung Yue River, Shek Sheung River, Kam Tin River, Shan Pui River, Ngau Tam Mei Channel and Yuen Long Bypass Floodway. The document can be viewed in EPD's website.

5. SELECTION OF DESIGN APPROACH

5.1 SELECTION PRINCIPLE

According to Technical Memorandum on EIA Process (EPD, 1997), the general policy or approach for mitigating impacts on important habitats (natural streams/rivers in this case) is, in the order of priority, avoidance, minimization and compensation. Hence, from the environmental point of view, the principle for selection of design option should be in the same priority. The avoidance approach avoids direct impacts on the natural streams/rivers. Design options with such approach should be applied on natural streams/rivers, particularly ecologically important ones, to the maximum extent practicable. Where impacts on the natural stream/rivers are unavoidable, design options with the least impact (i.e. minimization of impact), while meeting the river regulation objective should be chosen. Compensation approach should be applied in the design when residual impact is still considered significant after impacts have been avoided and minimized as far as practicable. The three approaches are discussed in details in the following sections.

5.2 AVOIDANCE APPROACH

The "avoidance approach" in the river channel design for flood alleviation schemes usually refers to engineering solutions and operations to control flood which would either avoid or minimize any direct environmental impacts on any part of existing watercourses, including their in-channel and river-bank components. Common engineering solutions based on the avoidance approach include provision of:

a. distant flood banks;
b. two-stage (or multi-stage) channels;
c. relief or by-pass channels; and
d. flood storage

Typical options for the engineering solutions based on avoidance approach are shown in Figure 1. Some of these solutions, for example relief channels and multi-stage channels, can provide not only flood alleviation but also the potential to increase both the amount and diversity of riverine habitats (RSPB *et al.*, 1994, Hey, 1996 and Anonymous, 2000). The following sections provide some concise descriptions of these engineering solutions.

5.2.1 Distant Flood Banks

If extra land is not a problem, the distant flood banks offer the optimal solution for flood alleviation as well as conservation of riverine habitats.

In this method, the flood banks are set back from the rivers as compared to the traditional bank formation of trained rivers. The river is, therefore, allowed to meander freely within their bounds. As a result, there is little interference between the natural stability of the river and the artificial embankment.

The main advantage of this method is that the flood banks can be built in relatively lower sizes and the natural habitats of the main channel are kept relatively undisturbed with the in-stream and margin habitats and vegetation untouched. Care should be made to ensure that the flood banks are not too steep so as not to affect the passage of wildlife across flood banks. The floodway bounded by the flood banks can also provide opportunity for ecological development or as a sanctuary of wetland associated wildlife, although ad-hoc maintenance may be required from the drainage point of view.

The main constraint with this method is the space availability along and within the flood banks to spare for flooding. This will be a problem in developed areas. But in rural areas, it may work well with a modification in the land use pattern in the flood plain areas, which are inside the flood banks allowed for flooding.

5.2.2 Two-stage Channel

The construction of a two-stage (or multi-stage) channel is a technique which can be used as an alternative to avoid the widening in the original river bed yet provides significant increases in cross-sectional area during high flows, without increasing the channel width during low flows, and consequently reduces the likelihood of sedimentation. It can also be used for rehabilitating channels that are over-widened.

Two-stage channel is created by excavating the surface section of the flood plain adjacent to the river, thus the original river channel is preserved while higher flows are contained within the newly created berms. A "flexible" approach, where the excavations alternate from bank to bank, can be adopted to achieve specific purposes (e.g. to avoid private land or preserve large trees).

An ideal two-stage or multi-stage channel (Figure 2) will comprise a relatively wide corridor profile so that it opens out the river in a series of berms and slopes until it eventually spills out from the artificial embankment onto the wider flood plain area. Sedimentation at the created berms is, moreover, likely to occur and the vegetation on these will need to be managed to prevent the development of overgrown scrub which may impede flow during periods of flood.

Environmental benefits of this engineering solution are that different flooding regimes and water tables in each section of the channel will result in the development of different types of habitat and contribute to biodiversity. The construction of a two-stage or multi-stage channel in upland portion of a river is, however, less likely to be successful due to sedimentation, rapid bank erosion and destruction of created berm during flood flows. Moreover, land availability would pose a great constraint in applying this design.

5.2.3 Relief / By-pass Channel

Relief or by-pass channels are constructed channels with the aim of diverting excessive water from the main natural channel during periods of high flow, and consequently reduce the likelihood of flooding and erosion. When comparing this design with channel straightening, the original river, particularly the meandering sections, would remain undisturbed and with constant water flow during low and high flow situations. There are two broad types of relief channels:

a. Type 1: Relief channels which have permanent water flow can be designed to have either a small base flow even during the dry seasons, or the base flow can be shared equally between the relief channel and the main channel. This option is of great value to wildlife habitats because the riverine habitat in the relief channel can be created and maintained all year round, although care must be taken to ensure that sufficient flows are maintained in the main channel. Figure 3 shows the conceptual design of by-pass channel adopted in the drainage improvement in Luk Tei Tong River.

b. Type 2: Relief channels which are predominantly dry except during periods of high flow are less beneficial to wildlife, but may be less prone to erosion due to binding of the soil by a permanent cover of vegetation. This type of relief channels can be constructed in the form of underground box culvert to minimize land requirement. This option offers much less benefit to wildlife due to the lack of habitat creation but has an advantage of creating much less footprint than an open channel. Figure 4 shows the conceptual design of by-pass box culvert adopted in the drainage improvement in Pak Ngan Heung River.

Typically, relief channels are shorter than the original main channels, and consequently flow velocities in them are greater, which can cause scour and bed erosion. Such scouring and bed erosion, if allowed to worsen, can cause substantial widening and deepening in the relief channels. Ultimately, the majority of flow may be conveyed via the wider and deeper relief channel instead of along the original main channel. This may result in significant reduction of flow in the original main channel and thereby affect the original habitats living therein. Such potential problems can be avoided by protecting the channel sides and bed or by constructing a weir at the upstream inlet of the relief channel. If the relief channel is constructed such that it intercepts too much flow from the main channel, then increased deposition may occur in the main channel due to the decreased flow rate. Also, the angle at which the relief channel rejoins the main channel downstream should be acute to prevent scouring in the main channel.

The overall benefit of relief channels is that they provide an environmentally friendly and viable alternative to channel straightening or widening. They can satisfy flood alleviation requirements while creating more riverine habitats, instead of destroying it as is often the case with widening techniques. The drawback of this engineering solution is that a considerable amount of land will be required. However, comparing with the distant flood banks and two-stage channel, less land may be required for this option.

5.2.4 Flood Storage

The concept of flood storage is to intercept the runoff at the upstream area and temporarily store in a flood storage pond/area. When the water level in the downstream river recedes, water at the flood storage pond/area will be re-diverted into the river. This will substantially reduce the volume of runoff discharged into the downstream river during heavy rainstorm and flooding in low lying/downstream areas will also be relieved. The original river will remain undisturbed and with constant water flow at all times. If extra land intake is not a problem, flood storage offers an optimal solution for flood alleviation as well as conservation of riverine habitats.

5.2.5 Consideration for Selection

As can be seen from the above, depending on the actual site characteristics of areas prone to flooding, there are a number of options for flood alleviation without much disturbance to the natural riverine habitats. Creation of distant flood banks, where the banks are built along the edge of the meander belt, is the most preferred option as there is no impact either on the natural stability of the river or on the riverine habitats. Ecological stability is maintained since the natural environment of the river is kept.

In lowland urban areas, creation of multi-stage channel is a viable alternative as sedimentation can be minimal and the channel can actually increase the environmental value due to the addition of habitats and landscape features. Furthermore, the flood berms can be modified and maintained as an urban park or landscaping areas.

Table 1 provides the comparison of river channel design options under avoidance approach.

5.3 MINIMIZATION APPROACH

If the avoidance approach cannot be adopted, the following design options in river channelization are ranked in ascending order of environmental impact. In order to minimize impact, design should not be over-provided and the one with the least impact while meeting the river regulation objectives should be selected.

5.3.1 Bank Stabilization

This option involves the use of natural materials (e.g. rocks or vegetation) for bank stabilization in certain areas prone to erosion while the entire stream bed is left intact. See section 6.3 for more details.

5.3.2 Clearing and Removal of Obstructions

Removal of objects such as fallen trees, debris, or shoals within the river channels and clearing of vegetation in a selective manner can be an option to restore the river capacity in the river channel design. Desilting work carried out regularly as a routine maintenance measure also falls into this option. However, due considerations should be given to the frequency and phasing of dredging for desilting in order to minimize the ecological impacts during the operation. For some cases, bridge piers/decks, weirs and utilities crossings may cause obstruction or form bottle-neck to the channel flow, removal/relocation of these obstructions can also be considered.

5.3.3 Enlargement of Channel by Widening

The original river channel is enlarged by widening while the stream bed is left intact (Figure 5). River-bank enhancement measures should be applied and environmentally friendly embankment lining should be selected to reinstate the banks (see sections 6.3 and 8 respectively for more details). Where practicable, widening can be done by modifying one bank only and leaving the opposite bank intact. The bank on which the work is undertaken can be alternated in different sections and determined based on actual site situation in relation to engineering feasibility, the ecological value of the habitat and bank stability.

5.3.4 Enlargement of Channel by Deepening

The channel bed is excavated to a greater depth to increase the flow capacity. From an ecological perspective, this is undesirable as the construction process will remove the bed substrates and destroy the benthic habitat. This may change the natural fluvial process and the hydrological connectivity of river and flood plain. However, this may be the only option when extra land on both sides of the channel is not available and in such cases, design of in-channel enhancement measures and environmentally friendly channel bed lining are crucial (see sections 6.2 and 8 for more details). Alternatively, partial dredging can be undertaken to create a deeper channel in one part of the bed while maintaining sufficient base flow over the un-deepened part of the bed, in order that the impact on the benthic habitat is minimized.

5.3.5 Realignment / Straightening

The original river channel, usually where it is meandering, is realigned or straightened to increase flood conveyance capacity. However, the hydrology and ecology of the whole river, particularly the abandoned meanders, are significantly affected. Where practicable, the meanders could be preserved for ecological purpose but it should be borne in mind that careful design and regular maintenance will be required for their ecological sustainability (see section 6.4 for more details).

5.3.6 Use of Artificial Non-Vegetative Smooth Lining

Artificial non-vegetative smooth linings, such as concrete, are applied on the stream bank and/or stream bed to reduce the roughness and protect from scouring, thereby increase the flow velocity in the stream. This design has minimal land take, highest level of stability and requires less maintenance effort. However, the lined channel has minimal ecological value and is aesthetically unattractive. This design should be avoided as far as possible unless there are severe site constraints and other more environmentally friendly designs are proven to be impracticable. If the use of artificial non-vegetative smooth lining is unavoidable, sections of the natural channel or artificial substrates should be retained or provided respectively at intervals as refugee for aquatic organisms. Moreover, in-channel and river-bank enhancement measures and the choice of soft bedding and embankment materials can be used to enhance the channel aesthetically and ecologically.

5.4 COMPENSATION APPROACH

It is generally considered that ecosystems of natural streams and rivers are difficult to recreate. As such, compensating loss of riverine habitat due to river channelization through creation of a new river channel is very difficult. The impacts on natural streams and rivers should be avoided and minimized as far as possible and compensation approach should only be applied when there is no other alternative. Some recent examples of applying the compensation approach in Hong Kong are:

a. Restoration and enhancement of disturbed fish ponds have been carried out to compensate for the loss in fish ponds in the Shenzhen River Regulation project.

b. Wetland habitats will be created as compensatory measures for the fish ponds lost in the construction of the San Tin Eastern Main Drainage Channel and Yuen Long Bypass Floodway.

The option of compensating impact on a natural stream through restoration/enhancement of a degraded/channelized river can be further explored but it would be difficult to demonstrate that the compensation could be provided on a like-for-like basis.

6. ADDITIONAL DESIGN MEASURES

6.1 OBJECTIVES

Following the principle and approach of selection in the preceding sections, the selected design/option can be further enhanced by incorporating additional design measures for ecological purpose. Such additional measures, if properly installed, will further minimize the residual ecological impact of river channelization works or even have positive impact after completion. They are broadly divided into in-channel measures (i.e. within the channel) and river-bank measures. However, it should be noted that different enhancement measures serve different purposes. The goals of ecological enhancement to be achieved should be stated in advance. Monitoring on the achievement of such goals after the project has been completed will provide useful information for the design of future projects.

6.2 IN-CHANNEL MEASURES

6.2.1 Preservation / Reinstatement of Bed Substrate

Preservation of natural bed materials of the river corridor achieves the best result from the ecological viewpoint. Boulders, cobbles or coarse gravels provide habitats for fishes and for macro-invertebrates while natural earth bottom, particularly at inter-tidal section, is attractive to wetland birds. The natural bedding at Kam Tin River Channel is a good example which provides an inter-tidal section to wetland birds, see Figure 6. Alternatively, the original stream substrates can be stockpiled along the bank during construction stage and used for reinstating the stream bed after excavation. However, careful planning should be exercised to carry out the works in sections/stages to minimize disturbance to the original ecosystem and to allow time for the aquatic organisms to migrate. Wherever a natural habitat of special flora and fauna is identified and disturbance is found to be unavoidable, proper mitigation measures such as translocation, temporary migratory pathways, recolonization or compensation plan should be devised. Design of channel bed lining is further discussed in section 7.

6.2.2 Creation of Sinuosity

Although a sinuous channel is likely to be more expensive to construct than a straight one, a well-designed sinuous channel is more stable, aesthetically more pleasing, has a slower flow and provides a greater variety of flow conditions and aquatic habitats. Due consideration should be given to the velocity of river at the upstream section as scouring at outer bank might cause stability problem to the embankment and higher maintenance cost would be required.

6.2.3 Pools, Riffles and Falls

Weirs can be installed to create riffles, falls and pools. They will enhance diversity in water current velocity and habitat structure. The pools formed behind the weirs will trap organic debris which provides food sources for invertebrates. The falls and riffles will increase aeration in the river. The weirs can be constructed of boulders or logs. Figure 7 shows a typical design of weir constructed of boulders. Care should be taken in the design that the weirs will not be too high and vertical which form barriers to free passage for fish species and other aquatic organisms.

6.2.4 Vegetated Ledge / Aquatic Planting Bay

Vegetated ledges can be created by installing steel sheet pilings along the edges or in form of planting bays. Figure 8 shows the type of vegetated ledge formed by sheet piles. The vegetation in the ledge could provide ecological habitat as well as a silt trap for improvement of water quality. To ensure that the aquatic plant is properly established, the ledge should be installed at a location where water current is relatively slow (e.g. inside of a bend where point bar have been developed) and with constant water supply. It should be noted that vegetation will be washed away after heavy rainstorm and maintenance of the vegetation may be essential from the drainage point of view (e.g. weed cutting).

6.2.5 Weir and Fish Passage / Ladder

Weirs sometimes exist in rivers and channels due to various reasons such as Fung Shui or irrigation. This will produce a physical barrier preventing the free passage of fish and other aquatic organisms along the stream. Consideration could be given in the design, such as providing the weir in the form of a ladder-shaped water trough, to facilitate the free passage particularly for relatively unfragmented streams and those with records of migratory fish species. The steps and gradient of the trough should be as low as practicable. Provision of irregular surface and cavity on each step will also assist the movement of fish and other aquatic organisms.

6.2.6 Silt Deposition

Deposition of sediment in channels is inevitable. From hydraulic viewpoint the sediment shall be removed as soon and as much as possible to restore the channel flood conveyance capacity. From the ecological viewpoint, certain amount of silt deposition at the invert of the channel is beneficial to the ecosystem. The two considerations are conflicting to each other to certain extent. In newly designed channels, certain allowance should be made in the design to cater for the permissible deposition between desilting cycles. According to section 9.3 of the SDM, the current design guidelines are:

a. 5% reduction in flow area if the gradient is greater than 1 in 25.
b. 10% reduction in flow area in other cases.

By adopting the above criteria, a balance between hydraulic and ecological considerations may be maintained.

The above consideration is only limited to area where the flow is clean and unpolluted. In polluted environment the silt deposit will likely create odour and aesthetic problems and more frequent desilting might be necessary. On the other hand, the frequency, timing and phasing of desilting operations in ecologically important streams/rivers should be carefully considered in order to minimize the adverse impacts to aquatic communities.

6.2.7 Exclusion of Concrete Dry Weather Flow Channel in Channel Bed

A dry weather flow channel made of concrete is normally provided in non-tidal channels in order to minimize siltation during low flow condition. However, the presence of such dry weather flow channel will give rise to dry channel bed, lowering of groundwater level at river channel and fast velocity of flow in the dry weather flow channel, which are not favorable conditions for supporting aquatic life. Due consideration should be given to minimize the use of dry weather flow channel in the design of river channels except where it may be necessary to intercept and divert polluted flow from the channel.

6.3 RIVER-BANK MEASURES

6.3.1 Soft Bank Revetment Method

The use of concrete lining for bank revetment is both environmentally and aesthetically undesirable and should be avoided as far as practicable on environmental ground. There is a wide range of soft revetment materials and bio-engineering alternatives, ranging from the softer natural vegetative treatment (e.g. grass) to the harder gabion wall. More examples such as brush mattresses and coconut fibre roll are available at FISRWG (The Federal Interagency Stream Restoration Working Group) 2001. Design of embankment lining is further discussed at section 8.

6.3.2 Retention and Creation of River Margins

In addition to the choice of soft materials for bank revetment, the retention and creation of river margins are also essential. Margins, which are the damp areas between the normal water level and the terrestrial habitat, are very important habitats for wildlife as many specialised plants and associated animals occur only in this zone. These damp areas are usually considered as part of the riparian zone and are important for wildlife because of the special refuge habitats provided during both the flooding and non-flooding periods. They also serve as interface connecting aquatic and terrestrial habitats and are particularly important for amphibians which rely on both types of habitat to complete their life cycles. It is, therefore, important to ensure that the margins are retained as far as possible.

In case physical disturbance to the margins cannot be avoided, mitigation should be applied, usually in the form of the creation of new marginal habitats. Creation of margin habitats is shown in Figure 9. In general, margins should either be retained or created on at least one bank or at alternative sections between hard banks. The margin should be varied in height and profiles as well as width so that the diversity of the habitat can be ensured. Appropriate vegetation variability at the re-profiled margins can also provide more benefits to the wildlife.

6.3.3 Provision of Bends / Shelters

Bends or some man-made shelters such as local embayment can provide some refuge for aquatic life during the passage of flood water. Considerations can be given to the provision of hollow concrete blocks at the embankment to serve as shelters.

6.3.4 Bank Shaping

The shape of the channel should be trapezoidal in shape except where land is a constraint. Two-staged embankment is preferred for main drainage channels because the different flooding regimes and water tables will result in the development of different types of habitat and contribute to biodiversity. If land is constrained, the provision of berms/margin on one side of the channel (at full length or partially) may be considered as it will also enhance the biodiversity of the habitat.

6.4 PRESERVATION AND ENHANCEMENT OF CUT-OFF MEANDERS

After realignment or straightening of a river, the previous meandering sections will be left behind and the flow will follow the newly constructed channel. Such cut-off sections, depending on its original ecological value, are either backfilled for landscape purpose or preserved as aquatic habitats. In the latter scenario, the preserved meanders should be properly designed to provide a wide range of ecological habitats. Figure 10 shows one typical arrangement of preserving and enhancing a cut-off meander.

There are a number of local examples of meanders which have been cut-off after river regulation projects (e.g. The Yuen Long and Kam Tin Main Drainage Channels, Main Drainage Channels for Fanling, Sheung Shui and Hinterland). Recent experience demonstrates that its application should be carefully considered taking into account the possible conflicts with adjacent land use and the resources required for long-term maintenance. It may not be pragmatic to indiscriminately retain them all for ecological impact mitigation. Meanders with easy access would be susceptible to illegal dumping and unauthorized land use, resulting in potential degradation. The slow flow/stagnant water may also be seen as environmental nuisance by local residents. The situation may be even worse if there are sources of water pollution inside the meanders.

For those selected sections of cut-off meanders with high potential for enhancement, the inlet and outlet should be carefully designed to ensure that there is constantly sufficient water flow in the abandoned meander to maintain the water quality and ecological balance in terms of nutrients and food sources. The natural river bed substrates and the bankside vegetation should be preserved as far as possible. Enrichment planting of native species should be undertaken to establish the marsh or riparian habitats. Regular maintenance such as weeding of unwanted plant species, desilting of channel and removing rubbish trapped in the meanders is essential for the ecological sustainability of the cut-off meanders.

7. DESIGN OF CHANNEL BED LINING

The channel bed is where fishes, macro-invertebrates and other aquatic organisms dwell. From the ecological point of view, the choice of channel bed lining should be as close to the natural condition as possible. The use of concrete will defeat such a purpose and should be avoided wherever possible. There is a wide range of bedding lining and materials that can be considered for use. The pros and cons of these are discussed in the following. The suitability and adoption of each type of lining may be governed by the particular reach of river channel involved, its ecological value, the flow characteristics, etc and will involve a careful balance of these factors. It is therefore likely that a balanced choice may comprise different and/or composite linings for different sections of a river channel.

7.1 NATURAL / UNLINED BED

Natural or unlined bedding is the most preferred option with minimal impact on the environment. After excavation and trimming to the required level, the channel bed is left untouched or paved with original bed substrates to retain its natural condition. This option preserves the habitat of the eco-system and disturbance is only limited to that during the construction stage. However, the hydraulic performance is poorer than other types of engineered/lined channel bedding. The irregular surface of the natural bedding, or even with vegetation on top, would induce a higher roughness on the channel. Another constraint on the use of this type of bedding is the erosion problem. The lining can only be applied in locations where the flow velocity is low or otherwise scouring problem would be severe.

The most common application of natural bedding is at the estuary or near the very downstream of the channel. Figure 6 shows a very good example of the natural earth bedding of Kam Tin River Channel during low tide.

7.2 RIP-RAP LINING

Rip-rap lining is formed by a layer of different-sized, angular rocks or boulders. Sometimes the rip-rap is underlaid with a layer of filter fabric or granular materials. The gaps and spaces between the rocks and boulders provide good habitat for establishment of the aquatic communities. The overall appearance is also pleasant and indeed this type of lining is a close simulation of the condition of many natural rivers. However, the hydraulic performance is poor because the irregular surface of the rocks or boulders induces a high roughness over the channel section.

Scouring is a problem to be dealt with for this type of lining. The size and distribution of the rocks need to be properly designed to withstand the flow velocity and any scouring forces. This will in general limits the application to the middle to downstream portion of the channel only.

7.3 GABION / MATTRESS LINING

Gabion / mattress lining consists of wired gabion baskets filled with small to medium size rock or granular material, placed over the channel bed. This lining provides a moderate habitat for establishment of the aquatic communities. The hydraulic performance is moderate. The surface of gabion is irregular but the extent of irregularity is not as severe as rip-rap. The gabion bedding will be gradually covered by the gravels and silt which would accumulate over times.

Gabion bedding appears to be becoming more popular as compared with other options of channel bedding. However, its application in Hong Kong in the past is still limited and the performance is yet to be observed. Particular attention is to be paid for the design of the wires of the baskets as they are susceptible to corrosion. Furthermore, gabions are not suitable for areas subject to high scour action and flowing debris as the wires are prone to damage and will break. Besides unsightliness, damaged gabions require high maintenance efforts and costs in replacement. Rubbish trapped within the wires is also a potential management problem.

7.4 RUBBLE / STONES EMBEDDED IN CONCRETE / MORTAR

The rubble/stone embedded in concrete/mortar lining is indeed not much different from the concrete lining from the ecological viewpoint. It will hardly provide a suitable habitat for the aquatic communities. The main advantage over concrete lining is that it can provide a slightly better appearance.

7.5 GEOTEXTILE REINFORCED GRASS LINING

The channel bed is covered with top soil and grassed. A layer of geotextile woven fabric is provided underneath the top soil to reinforce the soil layer and to provide erosion protection to the bedding. It allows re-vegetation and provides good aesthetic condition. However, the bedding cannot provide a good habitat for establishment of the ecosystem due to the presence of the geotextile woven fabric. The hydraulic performance is better than that for rip-rap and gabion because of its softer revetment materials (grass) and its surface is less irregular. Maintenance cost on reinforced grass embankment is high as regular cutting of grass is required. It should be particularly noted that the strength of this type of lining is dependent upon the establishment of the grass roots. Hence, careful planning and timing of the construction schedule will be essential to avoid substantial damage to the lining by flood water before the grass roots are established. Reference should also be made to DSD Practice Note No. 3/2003 on the need to prevent erosion between hard and soft linings and at other areas of a river channel.

7.6 GRASSED CELLULAR CONCRETE PAVING

The channel bed is covered with interlocking hollow concrete panels/blocks that are filled with topsoil and grassed. It allows some degree of re-vegetation and provides a green appearance. However, the bedding cannot provide a good habitat for establishment of the ecosystem. Hydraulic performance is moderate and is better than that for natural bed and rip-rap. Figure 11 shows the cellular concrete paving at the channel bed of Yuen Long Bypass Floodway under construction.

7.7 Different types of channel linings have their pros and cons from different perspectives. A brief comparison on the construction cost, re-vegetation capability, ecological value, visual appearance, hydraulic performance and cost of maintenance is given in Table 2.

8. DESIGN OF EMBANKMENT LINING

Same as for channel bed lining, the use of concrete lining for bank revetment is both ecologically and aesthetically undesirable and should be avoided, unless there are severe site constraints (land problem and/or stability issue). The different types of lining and revetment materials that can be used are more or less the same as those described for the channel bed, except that these are applied at the two sides of a river channel.

8.1 NATURAL / UNLINED EMBANKMENT

Natural or unlined embankment with vegetative treatment is an option with minimal impact on environment. This option preserves the riparian habitat. However, the hydraulic performance is lower than other types of engineered/lined channel embankment because the irregular shape and surface of the natural bank and the vegetation on the side slope would induce a higher roughness over the channel sections. This option is applicable to areas where land is available or the consequence of flooding to surrounding area is less significant. The major drawback of natural or unlined embankment is the erosion and settlement problems that may lead to slope failure or damage to the embankment, giving rise to an unsafe situation that may affect the public and nearby properties. The application of this option may not be appropriate for areas susceptible to scour action of high velocity flow or abrupt change in flow direction. More frequent inspections and maintenance efforts are required to prune excessive growth of vegetation and repair damaged bank.

8.2 RIP-RAP LINING

Rip-rap embankment is flexible and will not be impaired by slight movement from future settlement or other adjustments. The gaps and spaces between the rocks or boulders, which are usually bigger than those in gabions, provide good habitats for aquatic organisms during high flow and establishment of riparian vegetation in a longer term. The visual appearance is also very good. However, the hydraulic performance is low because the irregular surface of the rocks or boulders induces a higher roughness over the channel section. Compared with gabion, rip-rap cannot be applied on steep side slope. So the land requirement for rip-rap is larger than that for gabion. The maintenance cost of rip-rap embankment is moderate. However, as rubbish can be easily trapped in rip-rap lining and cause environmental nuisance, more frequent clearing work is required. Figure 12 shows the rip-rap embankment at Shan Pui River Channel.

8.3 GABION WALL / MATTRESS LINING

Gabion baskets can be used to form vertical river embankments by placing the baskets in single layer or multiple layers in steps, depending on the depth of the channel. One typical example is the gabion embankment at Luk Tei Tong River (see Figure 13). Sloping embankments can also be formed by gabion mattress which is laid at a flattened slope. Vertical gabion walls usually have a tilted slope of 6° and a foundation mattress extending out to protect the toe of the wall from undermining. However, gabion embankment may not be suitable for areas subject to the scour action from high velocity flow or abrupt change in flow direction as the wires of the baskets are susceptible to corrosion and abrasion. Damaged gabions require high maintenance efforts in replacement as the baskets are usually laid in layers which are offset to increase their strength.

Where possible and applicable, the slope of gabion embankment should be made gentler to avoid obstructing the movement of terrestrial animals across the river. Gabion embankment provides moderate habitat for establishment of the ecosystem within the newly constructed drainage channel and it also allows re-vegetation. However, the hydraulic performance is low because the irregular surface of the gabion baskets and the rocks filled inside the basket induces a higher roughness over the channel sections. For deep drainage channel, it requires a great extent of land for the construction of the gabion due to its thickness. A composite structure of concrete retaining wall with gabion lining may be an option.

8.4 GEOTEXTILE REINFORCED GRASS LINING

Geotextile reinforced grass may be used to line a river embankment. However, due to the presence of the geotextile woven fabric, it does not provide a good habitat for wildlife along the newly constructed river embankments. The hydraulic performance is better than that for rip-rap and gabion because its surface is less irregular. The maintenance cost of reinforced grass embankment is high as regular cutting of grass is required and there are chances of damage to the embankment under very strong flow of flood water. Typical examples of such river embankments are found in the rehabilitation works at Ng Tung River and Sheung Yue River (see Figure 14).

8.5 GRASSED CELLULAR CONCRETE PAVING

This method has been commonly adopted in the recent drainage channel projects. It allows some degree of re-vegetation and provides a green appearance. The hydraulic performance is better than that for rip-rap and gabion because of its surface is less irregular. However, the grassed cellular concrete paving would not provide a good habitat for establishment of the bankside ecosystem within a newly constructed river channel. If sufficient silting materials are left on the concrete surface, habitats may start to form. Maintenance cost on the grassed embankment is high because regular cutting of grass is required. Typical example of this type of embankment lining can be seen along the section of Kam Tin River from Kam Tin San Tsuen to Wang Toi Shan section (see Figure 15).

9. LANDSCAPE AND PLANTING

It is imperative that the landscape design of a river channel is conducted in parallel with the engineering and ecological elements. It is only through the co-ordination of all three elements that a drainage infrastructure which is visually pleasing, ecologically valuable and effective in engineering performance can be achieved. Designing the channel and then adding a landscape fringe as an afterthought may not achieve such an objective.

Every channel is different and it is not possible to provide standard designs applicable to all channels. The existing channel must be assessed, and the new channel designed to mimic the existing one as far as possible in terms of species selection both in the channel and on the banks.

Plants play an essential role for wildlife and aquatic communities. Channel widening may damage riparian vegetation together with its adjoining areas which would cause impacts to the aquatic communities and its vicinity. In such case, landscape work can be considered to mitigate the impacts. The objectives of landscape and planting work are:

a. to enrich the ecological value of the riparian zone by using native and self-sustainable species as far as possible;
b. to mitigate the landscape and visual impacts along a river channel by providing green elements;
c. to mitigate ecological impacts by re-establishing the terrestrial and riparian habitats along and within the river channel;
d. to create shelter or shade for invertebrates; and
e. to provide leaf litters as food source for the wildlife and aquatic organisms.

9.1 ASSESSMENT OF LANDSCAPE AND VISUAL IMPACTS

To establish a basis for the formulation of landscape and planting designs, it should be prudent to carry out in the first place an assessment of the landscape and visual impacts that will be caused by a river channel project. The scale of such an assessment will depend on the extent of impacts caused and the scale of the river channel project. Some of the essential considerations when conducting detailed impact assessments are highlighted in the following.

If the river channel project is a Designated Project under the EIAO (CAP 499), particular reference should be made to the Ordinance and relevant part of Technical Memorandum on EIA Process and EIAO Guidance Note No. 8/2002 "Preparation of Landscape and Visual Impact Assessment under the EIAO".

9.1.1 Baseline Study

a. Appraisal of the existing landscape and visual resources

The Baseline Study should include an appraisal of the landscape and visual resources of the assessment area focusing on the areas affected by the proposed drainage works such as woodland, farmland, village/ settlement, open storage, wetland, fish pond and scenic view of the river/stream itself. The landscape resources should be quantified and annotated on plan.

b. Tree survey/ vegetation studies

A tree survey should be conducted in order to:

i. identify those trees affected by the proposed drainage works, present opportunities to revise the layout so as to avoid valuable trees, and lead into any eventual tree felling applications to Lands Department;
ii. assess the tree stock, and use the information to guide the species selection. Any habitat assessment conducted as part of the ecological assessment will also provide useful information for the baseline survey and species selection.

As part of the tree survey, any trees in the Register of Old and Valuable Trees as defined in ETWB TCW No. 29/2004 - "Registration of Old and Valuable Trees, and Guidelines for their Preservation" within the assessment area should be identified and their potential impacts should be carefully assessed. Similarly, it should also include identification and assessment of other potential registered trees that meet one or more of the following criteria:

i. Tree of large size (e.g. tree trunk diameter ≥ 1m, measured at 1.3m above ground level);
ii. Tree of precious or rare species;
iii. Tree of particularly old age (e.g. ≥ 100 years old);
iv. Tree of cultural, historical or memorable significance; and
v. Tree of outstanding form.

9.1.2 Potential Landscape and Visual Impacts arising from the Drainage Improvement Works to River / Stream

Reference should also be made to the ecological impact assessment, if any is required to be done as part of the project, in respect of the quantification of special landscape features and the potential impacts on them and assessment of waste management in respect of potential loss of topsoil.

The key impacts arising from the temporary and permanent drainage improvement works of the river/stream may include the following:

a. Loss of fish ponds and marshes;
b. Loss of active fallow farmland;
c. Loss of topsoil;
d. Clearance of riparian soft edge, trees, woodland, scrubland, grassland and mangrove;
e. Change in river/stream courses: loss of meanders, cascades and the visually interesting natural course of river/stream being replaced by straight embankment.

9.1.3 Typical Mitigation / Enhancement Measures

Alignment that may create adverse landscape and visual impacts such as felling of any old and valuable trees should be critically reviewed to see if other alternative alignments with less landscape and visual impacts are viable.

Typical mitigation measures may include the following in the order of importance:

a. Retention of existing banks and riparian vegetation
b. Avoidance of straight alignment
c. Aesthetic design of channel embankment
d. Provision of planting on the channel bed, embankments and the areas along the top of channel where required by EIA report
f. Provision of artificial wetland
g. Restoration of fish pond

9.2 PLANTING DESIGN FOR RIVER CHANNEL

9.2.1 Criteria for the Choice of Species

Planting design is a comprehensive consideration of design objectives/theme, microclimate, site constraints, soil conditions and budget for initial cost, subsequent maintenance commitment and other environmental and engineering considerations. The success of mitigation planting depends on proper selection of species. Reference can be made to the ecological impact assessment where species recommended for compensatory planting can usually be found, whilst at the same time taking note of any identified insurmountable engineering constraints for the planting design. Coordination and consultation with ecologists and engineers to avoid conflict of the planting design with the wildlife and daily operation of the engineering works are highly recommended. The criteria for the choice of species therefore may include:

a. Colour, texture, habit and form of plant materials

Depending on the design objectives/ theme and other relevant considerations, it may be necessary to introduce plant species with different foliage colour, texture, habit and form so as to enrich the visual attractiveness of planting in riparian zone and for breaking up the monotonous linear nature of the embankment.

b. Self-sustainable species

In consideration of the scale of planting at the areas along the top of channels, its embankments and channel bed (where required and applicable), self-sustainable species with low maintenance requirements is preferred so as to minimize the maintenance cost.

c. Native species

Where possible, native species should be planted to provide food and shelters for local wildlife of riparian habitats, particularly for the cases where the planting objectives are mainly for ecological mitigation.

d. Compatibility with the surrounding

Species growing vigorously in the surrounding areas of the channel give a good indication that such species can establish well in similar microclimate and can therefore be considered for further use.

e. Tolerance to alternate wet and dry condition (for the species to be planted on toe zone and channel bed)

The depth of water inside the channel may vary considerably during the wet season (April to October) and dry season (November to March). In the wet season, the plant species may be submerged below water, however, in dry season, the channel bed may dry out and the plant species may be exposed in the air and grow in a comparative dry condition. Hence, the selected species should be tolerant in both wet and dry conditions and have ability to survive in such extreme conditions and regenerate in the next growing season.

f. Non-woody Plants (for species to be planted on toe zone and channel bed)

Periodic pruning is required for maintenance of vegetation. Non-woody species is preferred for ease of maintenance and pruning as they are easier to be pruned and will impede the flow of water to lesser extent during large flow as the vegetation will just collapse and spring back.

g. Tolerance to saline environment (for species to be planted in tidal zone)

For areas within tidal zone and areas subject to salt spray, species that can adapt to saline conditions should be considered.

h. Non-invasive root system species (for species to be planted on the channel bed, embankment and top of channel)

The scope and scale of planting works should be integrated in the design of the drainage channel so that the normal entitlement of soil to support plant growth will not be unnecessarily compromised. Root barriers or other suitable means can be proposed to minimize the effects of root action of some species. Alternatively, species with non-invasive root system should be used.

9.2.2 Planting at Channel Bed, Toe Zone and Embankment

a. Plants provided inside a drainage channel will act as obstruction to water flow and will significantly reduce the hydraulic efficiency of the channel, if the scale of such planting is large. It is thus desirable to avoid large scale planting at the channel bed and the portions of embankments below the design water level except where such needs are identified in a corresponding EIA Report. If planting is required at channel bed, toe zone or embankment, sufficient planting medium such as soil-mix should be provided so as to accommodate rootballs of the proposed plants in accordance with relevant clauses of the "General Specification for Civil Engineering Works". In addition, appropriate provision should be made to facilitate plant growth and to avoid the plant materials from being washed away during large flows.

b. Proposed plant list in channel bed or toe zone

The toe zone is the portion of the embankment that lies between the average high water level and the bottom of the channel. During the wet season, the water level will rise and the channel bed together with the toe zone will be flooded with water; however, in the dry season, the water level will drop and the channel bed with the exception of the dry weather flow channel and toe zone will experience dry condition. Hence, the proposed plants should be able to adapt to the alternate wet and dry conditions and have the ability to regenerate in the next growing season. A non-exhaustive list of suggested plants is given in Table 3.

c. Proposed plant list at embankment

The embankment is the area between the average high water level and top of the embankment. As this part is close to water table, the moisture content in soil is relatively high during the wet season. However, this zone is also affected by alternate wet and dry seasons. A non-exhaustive list of suggested plants is given in Table 4.

9.2.3 Planting along Channel Side

a. Structural component of channel side

This area is situated above the embankment. If planting is required in the area along top of channel to mitigate the landscape and visual impacts of the drainage works, sufficient planting medium such as soil-mix should be provided so as to accommodate rootballs of the proposed plants in accordance with relevant clauses of the "General Specification for Civil Engineering Works". In addition, the base of planting areas should be provided with a free drainage layer of minimum 150mm in depth.

b. Proposed Planting List:

A linear strip with proper landscaping can become a recreational resource. It can also provide good opportunity for creating woodland for wildlife. Hence, avenue tree planting with feature/ornamental trees and/or woodland mix planting with native species can be proposed depending on the design objective or theme. A non-exhaustive list of suggested plants is given in Table 5.

10. REFERENCES

10.1 American Society of Civil Engineers, *(1996) River hydraulics,* ASCE Press

10.2 Anonymous, 2000. *Management and Rehabilitation of Rivers and Lakes.* A technical paper containing descriptions of processes, functions and management techniques for river rehabilitation and management in the United Kingdom. Available at http://www.chm.org.uk/detail.asp?m=130

10.3 Brookes, A. 1988. *Channelized rivers: perspectives for environmental management.* John Wiley & Sons, Chichester.

10.4 Cowx, I.G. and Welcomme, R.L. 1998. *Rehabilitation of rivers for fish.* Fishing News Books, Oxford.

10.5 Dienst Landelijk Gebied (1999). *Working Together with Nature in the Dutch River Region.* Arnhem, the Netherlands.

10.6 DSD, 2000. *Stormwater Drainage Manual.* Drainage Services Department.

10.7 EPD, 1997. *Technical Memorandum of Environmental Impact Assessment Process.* Printing Department, Hong Kong. Available at http://www.epd.gov.hk/eia

10.8 FISRWG (The Federal Interagency Stream Restoration Working Group) 2001. *Stream corridor restoration: principles, processes, and practices.* Available at: http://www.usda.gov/stream_restoration

10.9 Hey, R.D. 1996. *Environmentally sensitive river engineering.* In River Restoration – Selected Extracts from The Rivers Handbook (ed. Geoffrey Petts and Peter Calow), 80 – 105. Oxford: Blackwell Science Ltd.

10.10 Hong Kong Government, 1992, General Specification for Civil Engineering Works

10.11 Hydraulics Research, Wallingford (report EX1799 September 1988). *Assessing the hydraulic performance of environmentally acceptance channels*

10.12 Margaret S Petersen, *(1986) River Engineering*, Prentice-Hall, Englewood Cliffs, N. J. 07632

10.13 Petts, G. and Calow, P. 1996. *River restoration,* Blackwell Science, Oxon.

10.14 B. Przedwojski, R. Blazejewski and K. W. Pilarczyk, *(1995) River Training Techniques – fundamentals design and application,* A.A. Balkema/Rotterdam/Brookfield

10.15 RSPB, NRA, RSNC (1994). *The New Rivers & Wildlife Handbook.* UK.

10.16 Schropp, M.H.I. and Bakker, C. 1998. *Secondary channels as a basis for the ecological rehabilitation of Dutch rivers,* Aquatic Conservation: Marine and Freshwater Ecosystems, **8**, 53-59.

10.17 Vivash R. 1999. *Manual of river restoration techniques.* Janes, M., Holmes, N. and Haycock, N. eds. Arca Press, Bedford.

10.18 Edited by Mark Morris and Jonathan Simm, *(2000) Construction risk in river and estuary engineering – A guidance manual,* HR Wallingford

10.19 Edited by John L. Gardiner, *(1991) River Projects and Conservation – a manual for holistic appraisal,* John Wiley & Sons Ltd.

11. APPENDIX

11.1 TABLES

11.2 FIGURES

12. ACKNOWLEDGEMENT

The contributions made by members of the working group are greatly appreciated. It is hoped that through detailed appraisals and incorporation of the environmental design approach and measures outlined in this document in the project planning and design stages,

the objective of producing a river channel design as environmentally friendly as possible, while meeting its engineering requirements of discharging stormwater in an efficient and safe manner, can be achieved.

(W H KO)
Deputy Director of Drainage Services

Table 1 Comparison of River Channel Design Options under Avoidance Approach

	Engineering and environmental performance		
Option	Advantages	Disadvantages	Design limitations
Distant flood banks	Habitats and flora in original river / stream unaffected	Large land intake Land resumption complication	Not suitable in urban areas Potential need to change agricultural practice in flood storage zone in rural areas
Two-stage channel	Habitats and flora in original riverbed and lower part of river bank unaffected	Large land intake Land resumption complication If berm surface becomes overgrown, design flood capacity is lost	May not be suitable in urban area Not suitable to upland-type rivers Larger space requirement
Relief channel and by-pass channel	Habitats and flora in original river unaffected	Flow in original river / stream may be affected	May not be suitable to upland-type rivers
Flood Storage	Habitats and flora in original river unaffected	Large land intake	Substantial site formation works may be required for the flood storage pond / area at upland rivers

Table 2 Brief Comparison of Different Types of Lining

	Natural/ Unlined	Rip Rap	Gabion / Mattress	Geotextile Reinforced Grass	Grassed Cellular Concrete	Rubble / Stone Embedded in Concrete / Mortar	Concrete
Ecological Value	Very Good	Good	Moderate	Moderate	Moderate	Bad	Bad
Re-vegetation Capability	Good	Moderate	Moderate	Good	Good	Bad	Bad
Visual Appearance	Good	Good	Moderate	Moderate	Moderate	Moderate	Bad
Hydraulic Performance	Poor	Poor	Moderate	Moderate	Moderate	Good	Good
Construction Cost	Very low	Low	Moderate	Low	Low	High	High
Maintenance Cost	Moderate	Moderate	Moderate	High	Moderate	Low	Low

Table 3 A Non-exhaustive List of Species Suitable for Planting at Channel Bed or Toe Zone

Wetland Plants

Canna generalis (大美人蕉)
Canna indica "variegata" (花葉美人蕉)
Cyperus flabelliformis (風車草)
Dracaena sanderiana variegata (斑葉富貴竹)
Dracaena sanderiana virens (富貴竹)
Eleocharis dulcis (荸薺)
Eleocharis plantagineiformis (野荸薺)
Hedychium coronarium (薑花)
Lepironia articulate (蒲草 / 肇慶草)
Nelumbo nucifera (蓮)
Nymphaea tetragona (睡蓮)
Schoenoplectus mucronatus (北水毛花)
Thalia dealbata (水美人蕉)
Zizania caduciflora (菰)
* *Acorus gramineus (金錢蒲)*
* *Alocasia macrorrhiza (海芋)*
* *Alopecurus aequalis (看麥娘)*
* *Bacopa monniera (假馬齒莧)*
* *Colocasia esculenta (芋)*
* *Commelina diffusa (節節草)*
* *Curcuma aromatica (郁金)*
* *Cyperus exaltatus (高稈莎草)*
* *Cyperus malaccensis var. brevifolius (短葉茳芏)*
* *Cyperus malaccensis (茳芏)*
* *Cyperus pilosus (毛軸莎草)*
* *Eleocharis ochrostachys (假荸薺)*
* *Equisetum debile (筆管草)*
* *Eriocaulon sexangulare (華南穀精草)*
* *Fimbristylis ferruginea (銹鱗飄拂草)*
* *Fimbristylis subbispicata (雙穗飄拂草)*
* *Hygrophila salicifolia (水蓑衣)*
* *Impatiens chinensis (華鳳仙)*
* *Juncus effuses (燈心草)*
* *Leersia hexandra (李氏禾)*

* *Lepidosperma chinese (炮仗草)*
* *Limnophila aromatica (紫蘇草)*
* *Ludwigia adscendens (水龍)*
* *Paspalum longifolium (長葉雀稗)*
* *Paspalum orbiculare (圓果雀稗)*
* *Paspalum paspaloides (雙穗雀稗)*
* *Pentasachme caudatum (石蘿藦)*
* *Phragmites karka (卡開蘆)*
* *Polygonum barbatum (毛蓼)*
* *Polygonum hydropiper (水蓼)*
* *Ranunculus scleratus (石龍芮)*
* *Rotala roundifolia (圓葉節節菜)*
* *Rumex trisetifer (長刺酸模)*
* *Sagittaria sagittifolia (慈姑)*
* *Scirpus littoralis (鑽苞蔗草)*

<u>Planting in Areas Affected by Brackish Water</u>

Lepironia articulata (筆慶草)
Schoenoplectus triqueter (蒲草 / 大甲草)
Suaeda nudiflora (鹽定)
Typha angustiflora (水燭)
Vetiver zizanioides (香根草)
* *Acrostichum aureum (鹵蕨)*
* *Cyperus malaccensis (茳芏)*
* *Fimbristylis ferruginea (銹鱗飄拂草)*
* *Paspalum vaginatum (海雀稗)*
* *Phragmites australis (蘆葦)*
* *Polygonum chinense (火炭母)*
* *Rumex trisetifer (長刺酸模 / 假菠菜)*
* *Scirpus littoralis (鑽苞蔗草)*
* *Sesuvium portulacastrum (濱莧)*
* *Sporobolus virginicus (鹽地鼠尾草)*

<u>(* denotes native species and those without * are exotic/ornamental species)</u>

Table 4 A Non-exhaustive List of Species Suitable for Planting at Embankment

Allamanda neriifolia (硬枝黃蟬)
Alpinia zerumbet 'variegata' (花葉艷山薑)
Canna generalis (大美人蕉)
Canna indica (美人蕉)
Dracaena sanderiana 'variegata' (斑葉富貴竹)
Dracaena sanderiana virens (富貴竹)
Duranta repens (假連翹)
Hedychium coronarium (薑花)
Ilex rotunda (鐵冬青)
Lagerstroemia indica (細葉紫薇)
Pittosporum tobira (海桐花)
Rhododendron pulchrum (紫杜鵑)
Rhododendron spp 'pink' (粉紅杜鵑)
Schefflera arboricola (八葉)
Strelitzia reginae (天堂鳥蕉)
Tecoma stans (黃鐘花)
Vetiveria zizanioides (香根草)
* *Adina pilulifera (水團花)*
* *Alocasia odora (海芋)*
* *Camellia oleifera (油茶)*
* *Eurya chinensis (崗茶)*
* *Ficus hirta (粗葉榕)*
* *Ficus hispida (對葉榕)*
* *Ficus pyriformis (舶梨榕)*
* *Ficus viriolosa (變葉榕)*
* *Gardenia jasminoides (梔子 / 水橫枝 / 白蟬)*
* *Glochidion hirsutum (厚葉算盤子)*
* *Glochidion zeylanicum (香港算盤子)*
* *Ilex asprella (梅葉冬青)*
* *Ilex pubescens (毛冬青)*
* *Ipomoea pes-caprae (海灘牽牛)*
* *Ixora chinensis (大葉龍船花)*
* *Lepidosperma chinese (炮仗草)*
* *Ligustrum lucidum (女貞)*
* *Ligustrum sinense (山指甲)*

- * *Litsea rotundifolia (豺皮樟 / 圓葉豺皮樟)*
- * *Melastoma candidum (野牡丹)*
- * *Melastoma dodecandrum (地稔)*
- * *Melastoma sanguineum (毛菍)*
- * *Paspalum longifolium (長葉雀稗)*
- * *Paspalum orbiculare (圓果雀稗)*
- * *Paspalum paspaloides (雙穗雀稗)*
- * *Phyllanthus emblica (油甘子)*
- * *Psychotria rubra (九節 / 山大刀)*
- * *Rhaphiolepis indica (車輪梅 / 石斑木)*
- * *Rhododendron simsii (紅杜鵑)*
- * *Rhodomytrus tomentosa (桃金孃 / 崗棯)*
- * *Schefflera heptaphylla (鵝掌柴 / 鴨腳木)*
- * *Uvaria macrophylla (紫玉盤)*
- * *Wedelia prostrata (鹵地菊)*

(* denotes native species and those without * are exotic/ornamental species)

Table 5 A Non-exhaustive List of Species Suitable for Planting along the Top of Channel

Trees

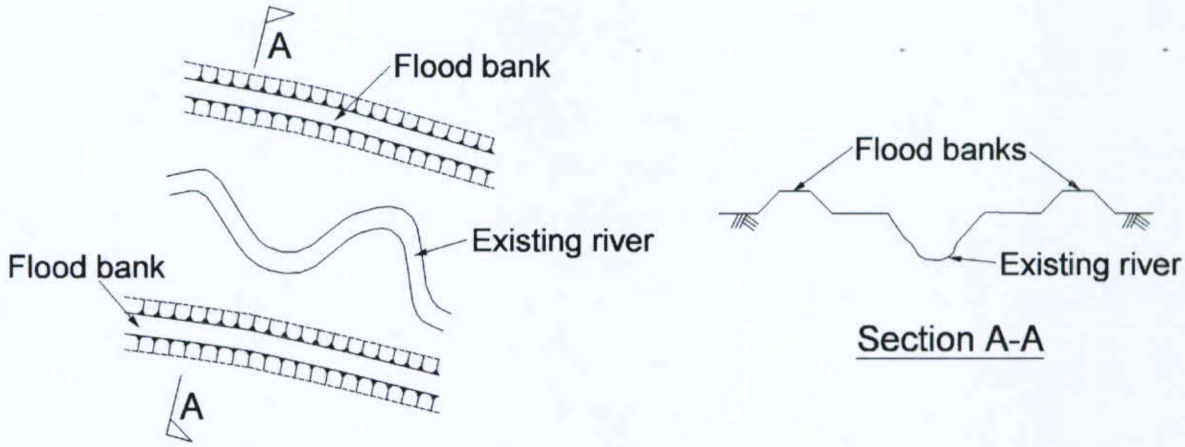
Aleurites montana (千年桐)
Bauhinia variegata (羊蹄甲)
Bauhinia variegata var. candida (白花羊蹄甲)
Callistemon viminalis (串錢柳)
Cassia fistula (豬腸豆)
Cassia surattensis (黃槐)
Chukrasis tabularis (麻楝)
Delonix regia (鳳凰木)
Dracantomelon duperreanum (人面子)
Elaeocarpus apiculatus (尖葉杜英)
Elaeocarpus hainanensis (水石榕)
Grevillea robusta (銀樺)
Ilex rotunda (鐵冬青)
Jacaranda acutifolia (藍花楹)
Livistona chinensis (蒲葵)
Pterocarpus indicus (紫檀)
Spathodea campanulata (火焰木)
Syzygium cumini (海南蒲桃)
Terminalia catappa (欖仁樹)
Toona sinensis (香椿)
* *Acronychia pedunculata (山油柑)*
* *Antidesma bunius (五月茶)*
* *Aporusa dioica (銀柴)*
* *Bambusa spp.*
* *Bauhinia blakeana (洋紫荊)*
* *Bischofia javanica (秋楓)*
* *Bridelia tomentosa (土蜜樹 / 逼迫仔)*
* *Castanopsis fissa (黧蒴錐 / 包衣稠 / 裂斗錐栗)*
* *Celtis sinensis (朴樹)*
* *Choerospondias axillaris (酸棗)*
* *Cinnamomum burmanni (陰香)*
* *Cinnamomum camphora (樟)*
* *Cleistocalyx operculatus (水翁)*
* *Cycloblalanopsis glauca (青剛櫟)*

* *Cycloblalanopsis mysinifolia (細葉青剛櫟)*
* *Diospyros morrisiana (羅浮柿)*
* *Elaeocarpus sylvestris (山杜英)*
* *Evodia lepta (三椏苦)*
* *Ficus fistulosa (水同木)*
* *Ficus microcarpa (榕樹 / 細葉榕)*
* *Ficus Superba var. japonica (筆管榕)*
* *Ficus virens (大葉榕)*
* *Garcinia oblongifolia (嶺南山竹子 / 黃牙果)*
* *Hisbiscus tiliaceus (黃槿)*
* *Ilex rotunda var. microcarpa (小果鐵冬青)*
* *Liquidamber formosana (楓香)*
* *Litsea glutinosa (潺槁樹)*
* *Litsea monopetala (假柿木薑子)*
* *Macaranga tanarius (血桐)*
* *Machilus breviflora (短花楠)*
* *Machilus chekiangensis (浙江潤楠)*
* *Machilus velutina (絨毛潤楠)*
* *Mallotus paniculatus (白楸)*
* *Media azadarach (森樹 / 楝)*
* *Microcos paniculata (破布葉 / 布渣葉)*
* *Phyllanthus emblica (油甘子)*
* *Pongamia pinnata (水黃皮)*
* *Reevesia thyrsoidea (梭羅樹)*
* *Rhus chinensis (鹽膚木)*
* *Rhus hypoleuca (白背漆)*
* *Sapindus saponaria (無患子)*
* *Sapium discolor (山烏桕)*
* *Sapium sebiferum (烏桕)*
* *Saurauia tristyla (水東哥)*
* *Schefflera heptaphylla (鴨腳木)*
* *Shima superba (木荷)*
* *Sterculia lanceolata (假蘋婆)*
* *Syzygium jambos (蒲桃)*
* *Viburnum odoratissimum (珊瑚樹)*

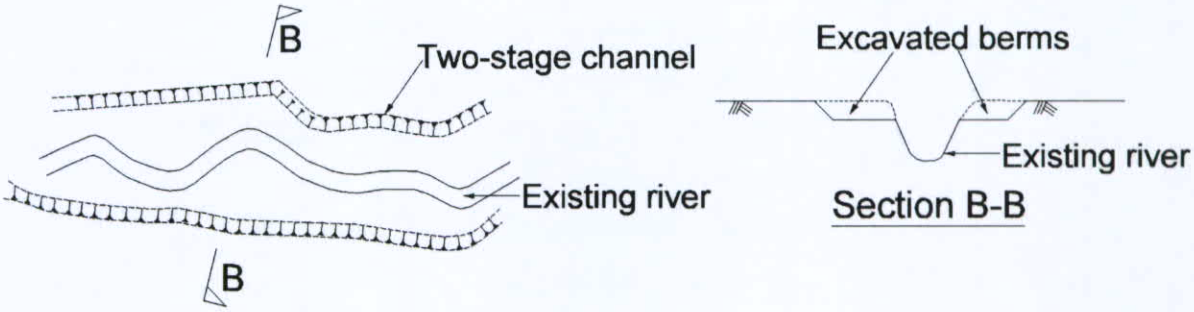
Shrubs

Aglaia odorata (米仔蘭)
Allamanda neriifolia (硬枝黃蟬)
Calliandra haematocephala (紅絨球)
Camellia japonica (山茶)
Cassia biscapsularis (雙莢槐)
Duranta repens (假連翹)
Hibiscus rosa-sinensis (大紅花)
Murrayra paniculata (九里香)
Nandina domestica (南天竺)
Pittosporum tobira (海桐花)
Rhododendron pulchrum (紫杜鵑)
Rhododendron spp 'pink' (粉紅杜鵑)
Sansevieria trifasciata (虎尾蘭)
Sansevieria trifasciata var. laurentii (金邊虎尾蘭)
Schefflera arboricola (八葉)
Schefflera arboricola 'variegata' (花葉八葉)
Tecoma stans (黃鐘花)
* *Camellia oleifera (油茶)*
* *Eurya chinensis (崗茶)*
* *Gordonia axillaris (大頭茶)*
* *Ixora chinensis (大葉龍船花)*
* *Ligustrum sinense (山指甲)*
* *Maesa perlarius (鯽魚胆)*
* *Melastoma dodecandrum (地棯)*
* *Psychotria rubra (九節 / 山大刀)*
* *Rhododendron simsii (紅杜鵑)*

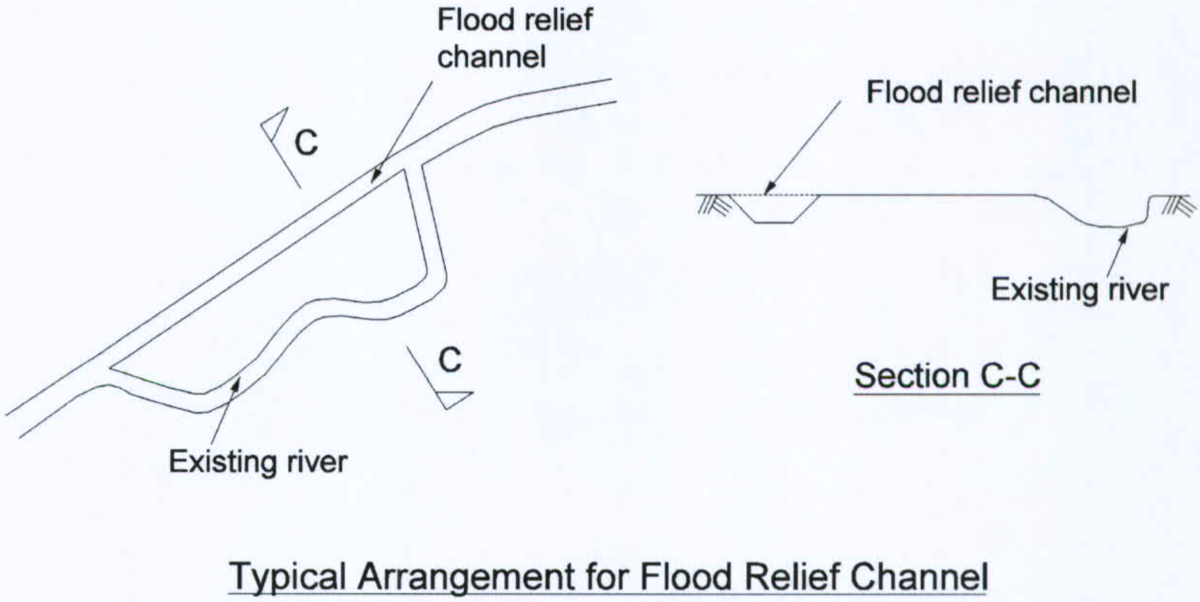
(* denotes native species and those without * are exotic/ornamental species)



Typical Arrangement for Distant Flood Banks



Typical Arrangement for Two-Stage Channel



Typical Arrangement for Flood Relief Channel

Figure 1 River Channel Design by Avoidance Approach

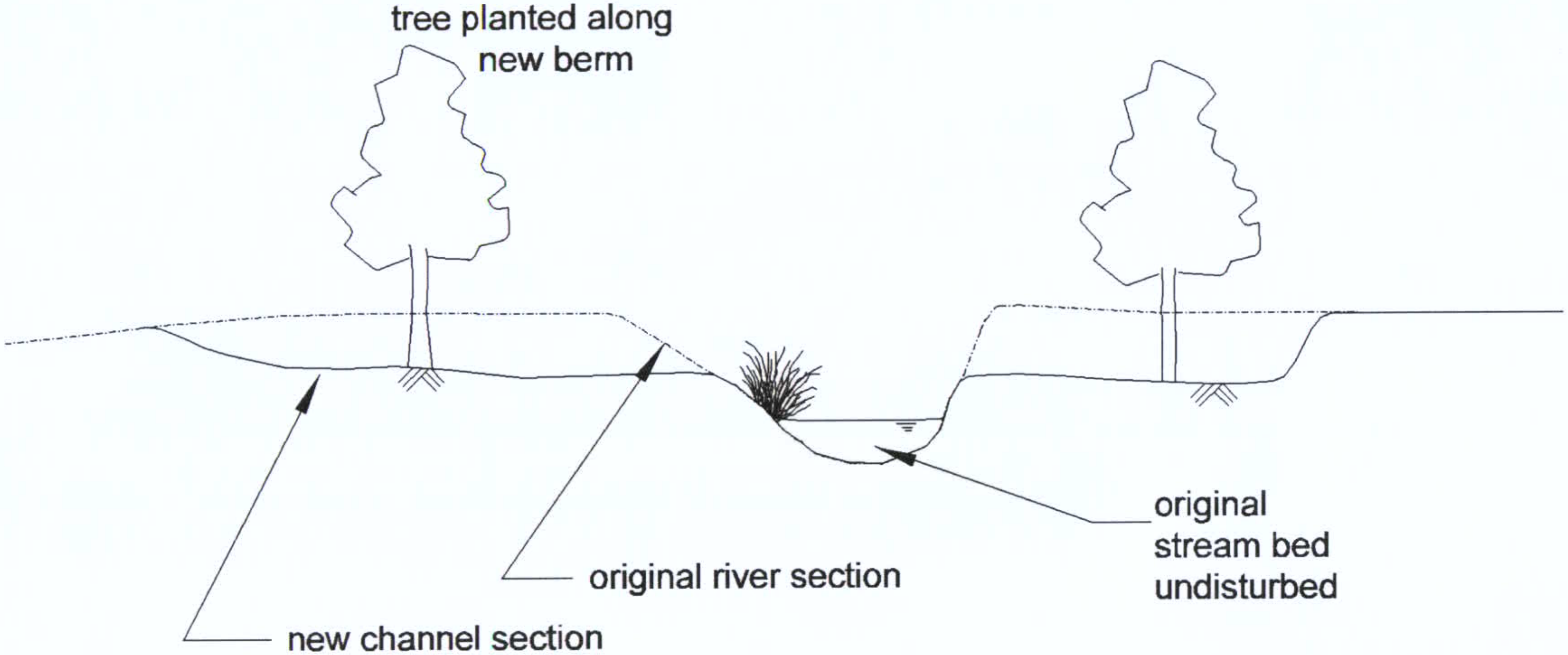


Figure 2 Two-stage Channel

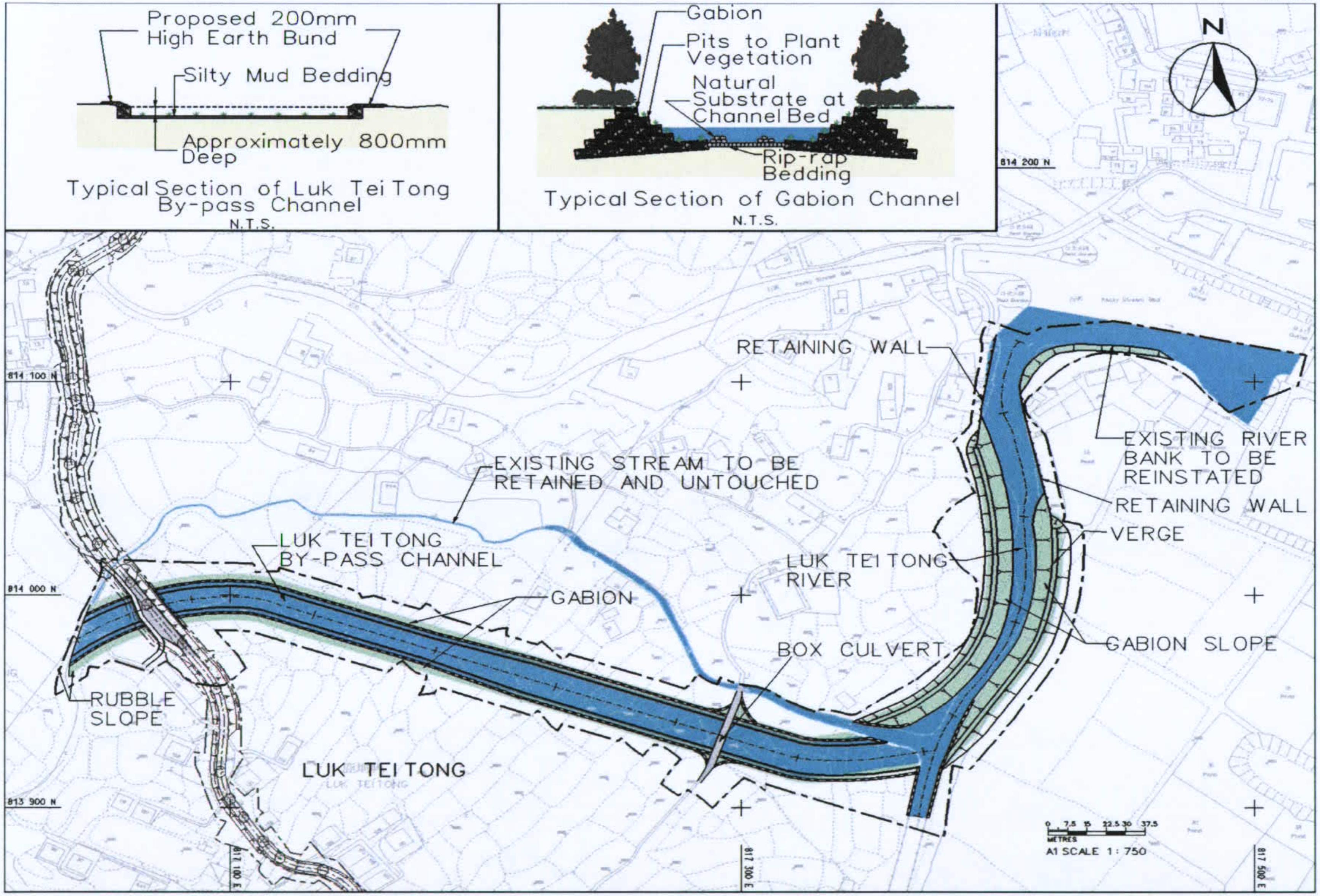


Figure 3 Conceptual Design of By-pass / Relief Channel adopted in the Drainage Improvement in Luk Tei Tong River

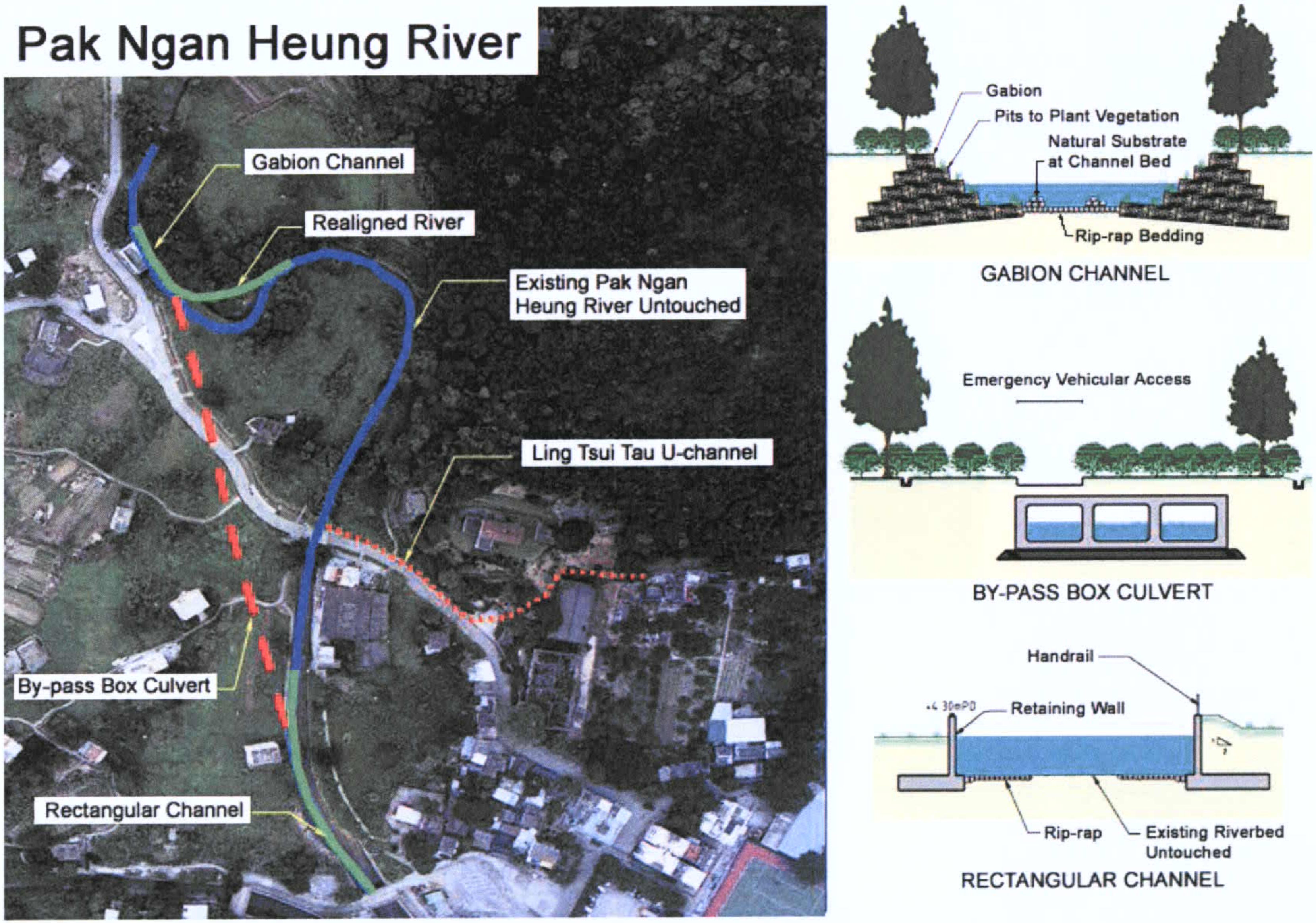
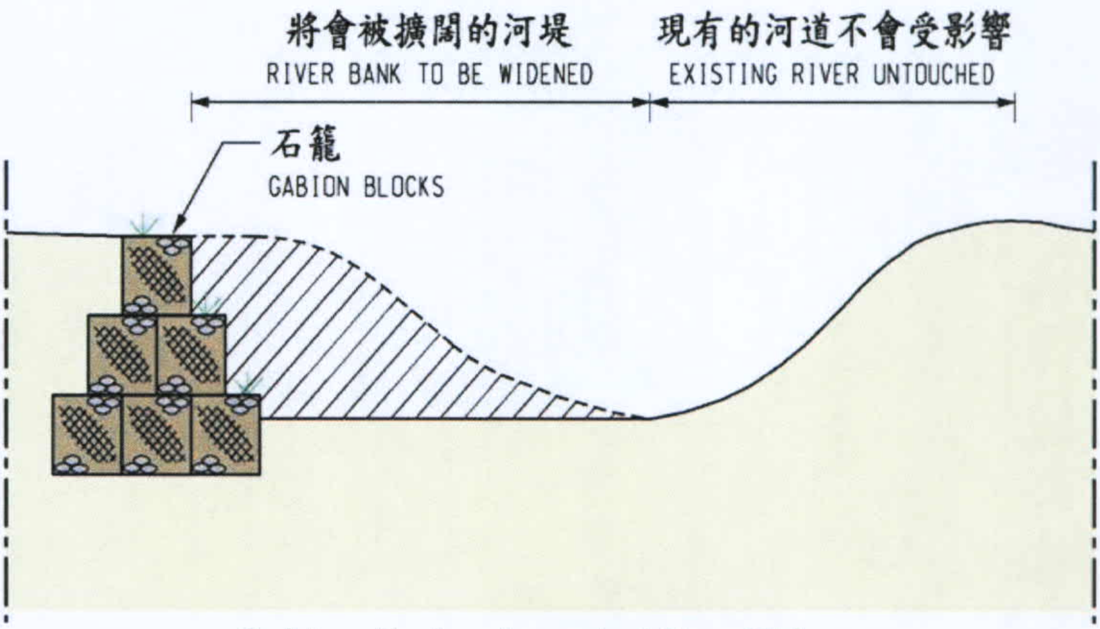
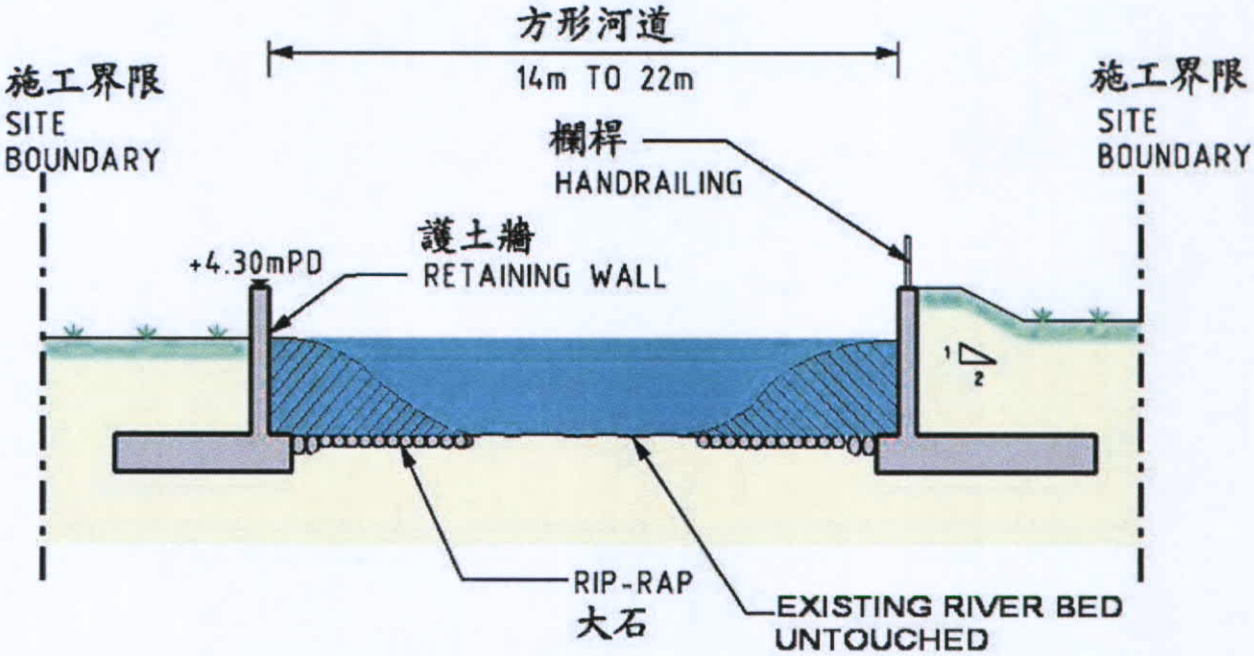


Figure 4 Conceptual Design of By-pass / Relief Box Culvert adopted in the Drainage Improvement in Pak Ngan Heung River



Gabion Embankment at One Side



RECTANGULAR CHANNEL

Figure 5 Typical Examples of Enlargement of Channel by Widening

Figure 6 Natural Earth Bottom of Kam Tin River Channel (seen during low tide)

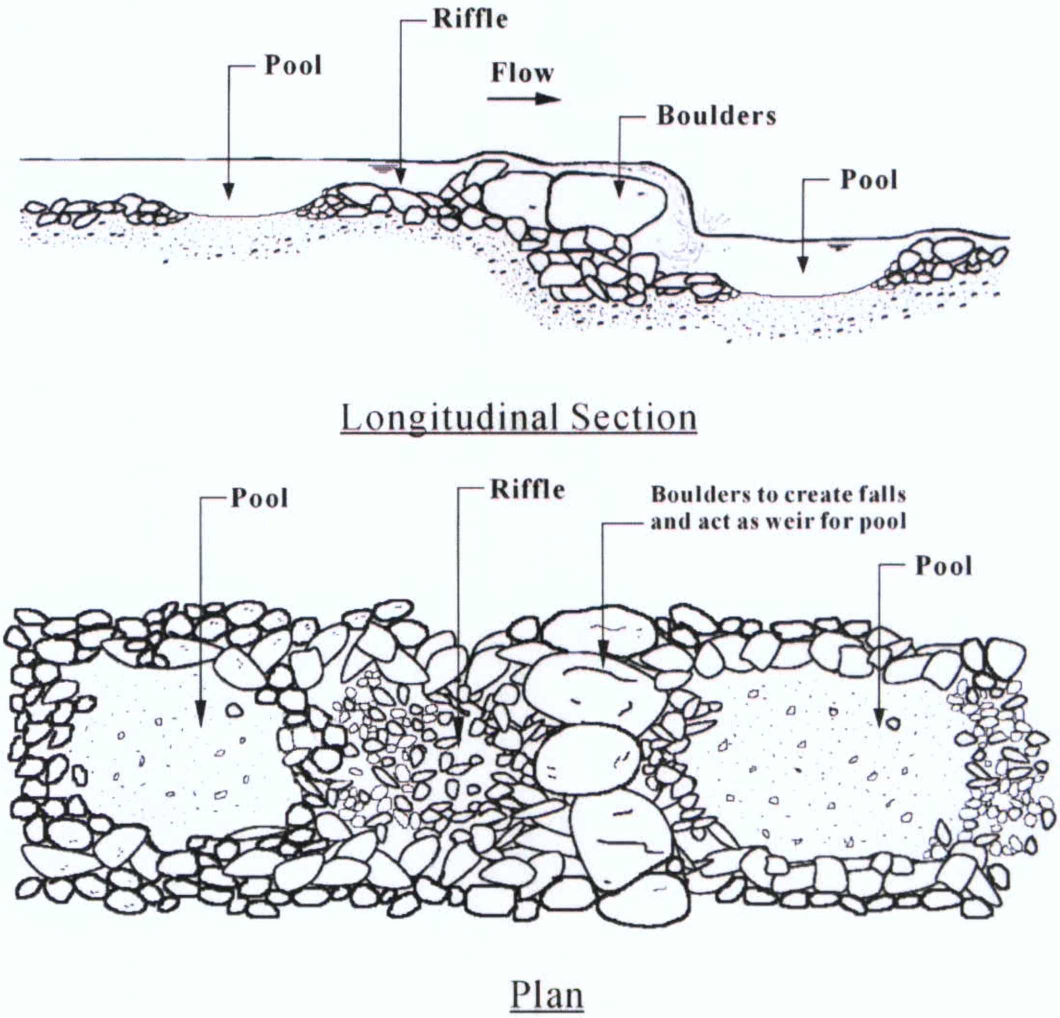


Figure 7 Creation of Riffles and Pools by Constructing Weir with Boulders

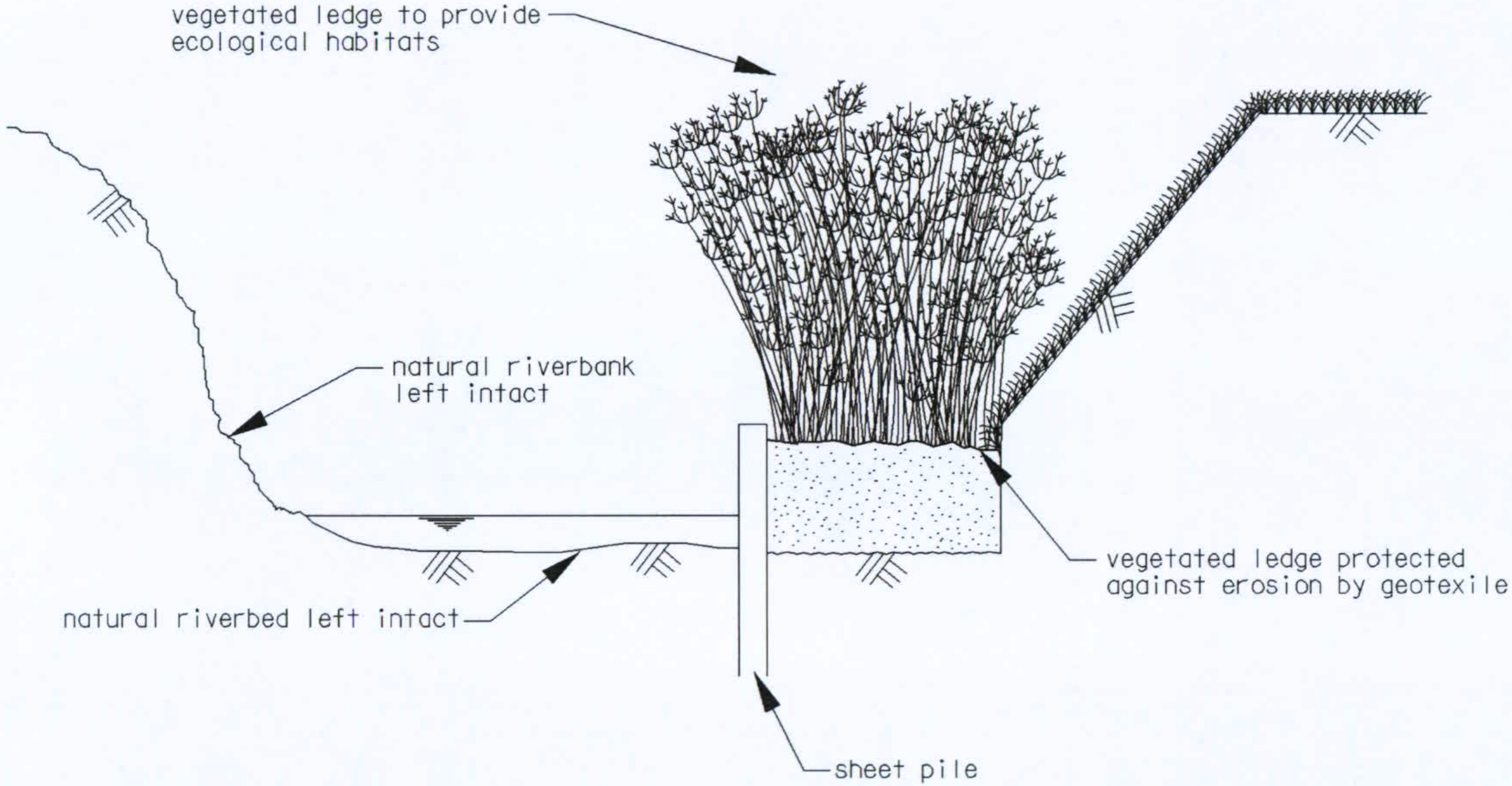


Figure 8 Creation of Vegetated Ledge by Sheet Piles

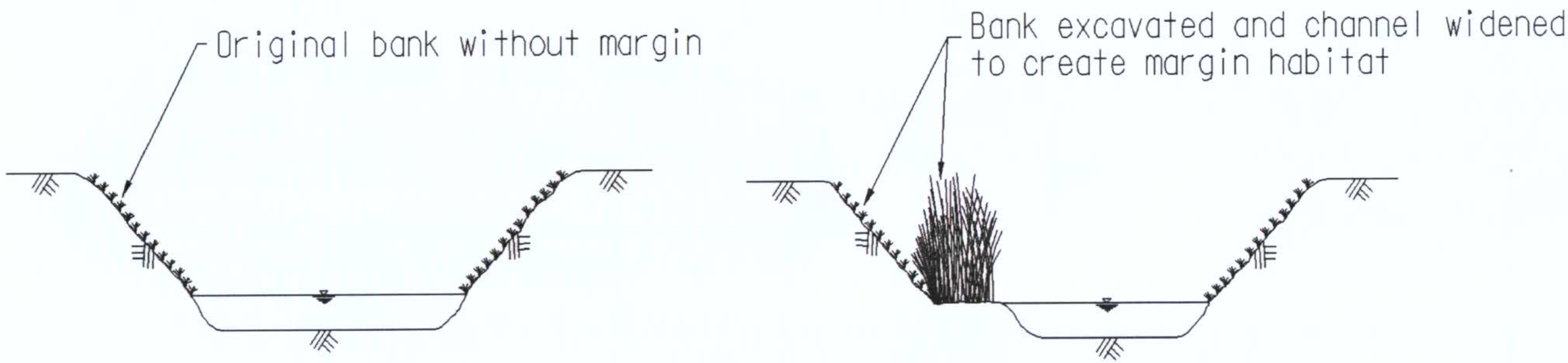


Figure 9   Creation of Margin Habitat

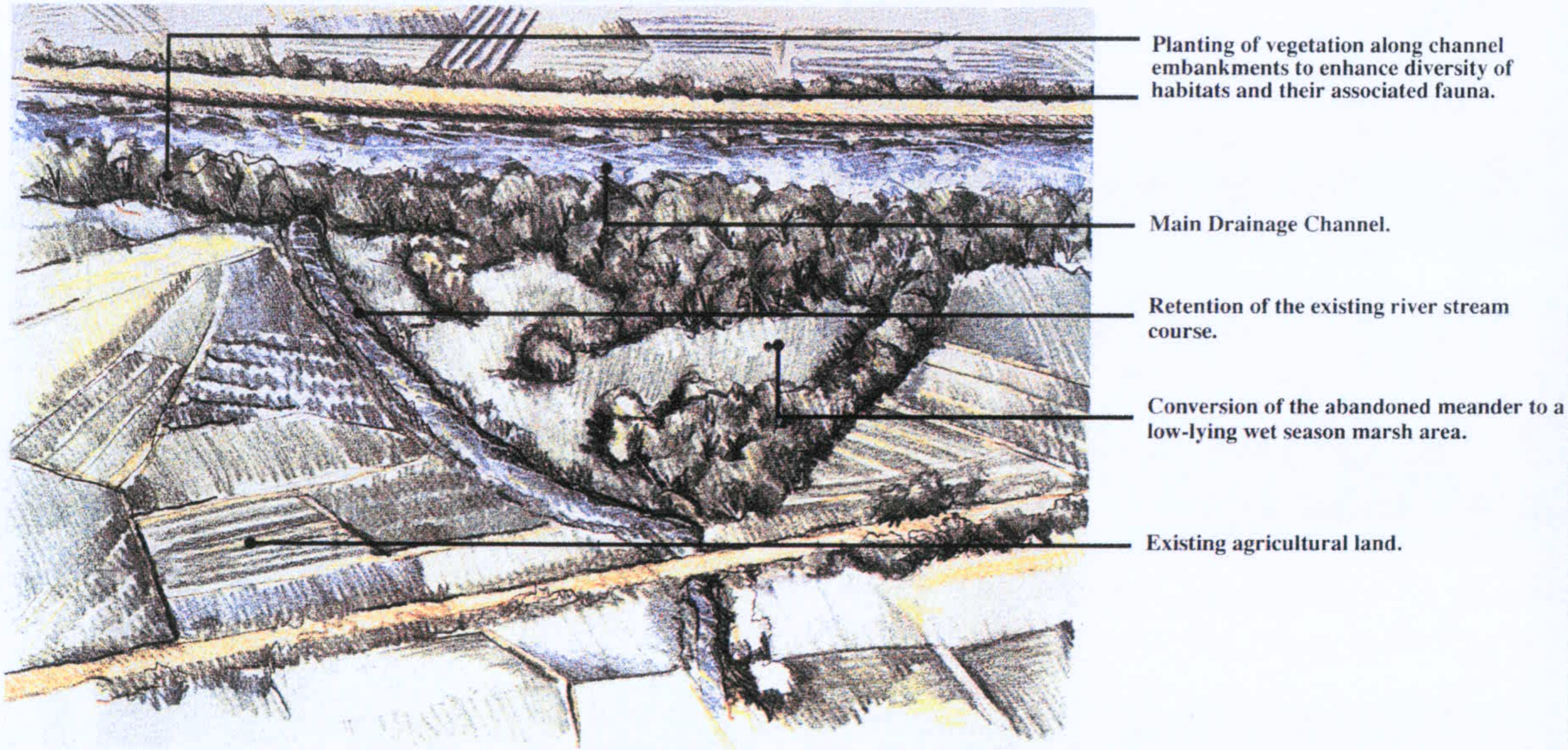


Figure 10 Preservation and Enhancement of Cut-off Meanders
Source: Examples of Environmentally Friendly Drainage Channel Designs Arising from Environmental Impact Assessments by EPD, DSD, AFCD & TDD

Figure 11 Grassed Cellular Concrete Paving at Yuen Long Bypass Floodway (under Construction)

Figure 12 Rip-rap Embankment at Shan Pui River Channel

Figure 13 Gabion Embankment at Luk Tei Tong River, Mui Wo

Figure 14 Geotextile Reinforced Grass Lining at Sheung Yue River

Figure 15 Grassed Cellular Concrete Paving Embankment at Kam Tin River