1 *Introduction*

Approximately 3.43 ha of land within the site boundary on the east side of the Eastern Channel will not be required for permanent works, and is available to provide wetland compensation via wetland creation and restoration. The area is bounded on the eastern side by the expanded Lok Ma Chau kiosk site and on the west by the Eastern Channel.

The objective of creating and restoring wetlands on this site is to create freshwater and possibly brackish-water habitats, including small ponds and shallow marshes, useful to waterbirds currently or historically found at San Tin. To this end, the design of this wetland area will provide habitats attractive to waterbirds and also to the invertebrates, amphibians and fish upon which they feed. Because different bird and prey species require different habitats, the objective of design will be to provide shallow (10-15 cm depth) marsh habitats with gently sloping bunds, some with emergent vegetation, in combination with open-water habitats with deeper water depths. This will provide a diversity of habitat types within the limited area available. A second objective is to design the wetland as a self-sustaining system, requiring little or no maintenance beyond routine tasks such as removal of invasive vegetation. A third objective is to design the wetland area as a visually attractive feature which enhances the landscape.

In addition, it will be important for the design and construction of this wetland area to mesh intelligently with design and construction of the constructed reedbeds proposed as ecological mitigation for the expansion of kiosks and other facilities at Lok Ma Chau Boundary Crossing (BBV 1999), identified herein as the "ASD reedbeds". Two of the proposed reedbed sites are adjacent to the constructed wetland site proposed under this study, and there is considerable potential for beneficial interfaces between the two projects' mitigation areas in water supply, drainage, planting and other aspects of design and construction. These reedbeds will be constructed during Phase 2 of the kiosk expansion, Apr. 2000-Dec. 2002.

2 *Design*

The site proposed for wetland creation has several inherent limitations. One is the lack of year-round freshwater supply. Another is the potentially high disturbance levels from the adjacent Lok Ma Chau Kiosk area. A third is the long, narrow shape of the site, which will maximise "edge effects" and potential disturbance levels throughout the site. A fourth is isolation from wetlands to the west, due to the presence of the Eastern Channel embankments. However, this is the largest contiguous area available within the site boundary for creation of such a wetland area. The area will be designed to maximise its advantages and overcome its natural disadvantages, in order to provide the highest degree of ecological value possible. Interface with the ASD reedbeds will create opportunities to mitigate some of these limitations, by increasing the width of the area covered by wetland and providing a source of water. Coordination between ASD and TDD in design and construction of these wetland will be essential, particularly to establish appropriate site levels and water depths, sources of water and drainage, and plant species to be used in initial plantings on the sites. Successful coordination will greatly increase the ecological value to be realized from these sites.

A schematic design for a section of the constructed wetland is shown in *Figure 1*, which also shows the location of an adjacent ASD reedbed. Sample cross-sections of the wetland are shown in *Figures 2* and *3*; the former shows a section without adjacent ASD reedbed, and the latter with adjacent ASD reedbed. More detailed layouts for the entire extent of the wetland area should be drawn up at the detailed design stage.

The main body of the wetlands, ranging in width from 5 to 40 m, will consist of an earthen substrate at a variable level, lower than the level of the San-Sham Road and Lok Ma Chau Kiosk area but for the most part higher than the bottom elevation of the Eastern Channel. The purpose of varying the bottom level is to ensure that wetlands of different depths are available during both the wet and dry seasons, since shallow depths are important for some wetland-feeding bird species. Where the eastern edge of the wetland area, is adjacent to the Lok Ma Chau kiosk area or San-Sham Road, it will consist of an earthen bund at a slope of approximately 1 in 2: no greater, to minimise erosion risk, but no less, to maximise wetland area. Where the eastern edge abuts ASD reedbeds, there will be potential to site the two wetland areas at the same level, or with the reedbed slightly higher to ensure drainage toward the Eastern Channel (see *Figure 3*). Correct setting of levels will facilitate water movements and maximise wetland area. The western edge of the constructed wetland will abut on the outer embankment of the Eastern Channel.

Most areas of the site will require some excavation to achieve the required depths. All controls and mitigation measures prescribed for earthworks in *Section 4.4.4* and Paragraphs 3.6.4.20-3.6.4.21 should be implemented during construction of this wetland area.

DSD has indicated that access to the Eastern Channel from the eastern side will be required, and an appropriate point should be selected at the detailed design stage at which an access point can be provided. One point at which a road crossing would not fragment the constructed wetland is the point roughly 400 m from the south end of the channel where a gap exists between the two parts of the constructed wetland. Otherwise, access should be at the northern or southern end of the wetland, to minimise disturbance and fragmentation of this compensation area.

TDD will be responsible for funding and implementation of the detailed design and construction of the constructed wetland area. The design team will take ecological issues fully into account, in recognition that the purpose of this area is ecological mitigation, and will seek input and comment from outside parties with the necessary expertise as appropriate. Such parties will include AFD. Construction, including installation of required drainage systems as outlined below, should be undertaken by contractors. The planting and hydroseeding works outlined below should be undertaken by a landscape contractor. Construction and planting of the area should take place simultaneous with or immediately after the completion of Eastern Channel construction.

3 ***Water Source and Drainage***

As there is no reliable source of clean water supply to this area, it is proposed that the area receive hard-surface runoff and treated sewage effluent from the Lok Ma Chau kiosk area, San-Sham Road, and local access road to the east. Sewage effluent from the Kiosk area is anticipated to be of acceptable quality, probably better overall than Shenzhen River water. Hard-surface runoff is also expected to be of fairly good water quality, as it will pass through gully pots and oil and grease interceptors and undergo natural treatment in passage through the ASD reedbeds. The strip of trees and non-wetland vegetation on the eastern verge of the wetland will act as a filter strip to further remove excess nutrients and contaminants before the runoff reaches the wetland proper. Filter strips, consisting of bands of vegetation that are not intensively maintained, are a highly effective, low-maintenance method of reducing the amount of nutrients and contaminants in surface runoff. The vegetation established in the wetlands will provide a final level of cleansing to runoff. To achieve the highest degree of self-cleansing, runoff should enter the wetland area over the surface, not through subsurface drains. A similar approach has been taken in compensatory ponds created at the Au Tau Interchange of Route 3 Highway, where road runoff is allowed to feed the ponds. It is understood from ASD that runoff at some times of the year is expected to be greater than required for reedbed maintenance, and there will be potential to direct any excess runoff diverted away from the ASD reedbeds into the constructed wetland. The quantity and quality of water available to the constructed wetland will be subject to coordination between ASD and TDD during the detailed design stage. Options for delivery of runoff and sewage effluent to the constructed wetland will be limited by the design of drainage systems that will be installed before the end of 1999; means must therefore be sought at the detailed design stage to work within these constraints to find the most rational and effective water delivery system. Since these issues will be resolved at the detailed design stage, drainage interconnections between the ASD reedbeds and the constructed wetland are not shown in *Figures 1* through 3.

Maintaining a pumped water input to the constructed wetland is not recommended, due to maintenance requirements which go against the principle of establishing a self-maintaining system. Additional water supply will be available through runoff and rainfall during the wet season and from groundwater; the deepest pools in the constructed wetland should be excavated to a depth adequate to allow groundwater recharge.

Internal water circulation within the wetland area should be maximised. The wider and deeper parts of the wetland should be interconnected by surface flows through the narrow necks that occur in several places on the site. Swales should be excavated through these narrow sections of the site to a depth adequate to allow water to pass between the wider and deeper parts of the wetland during the wet season, and if feasible during the dry season as well.

The wetland will have several outlets to the Eastern Channel, which will receive overflow from the wetland during the wet season. Each area of deep water shall be fitted with one outlet, as shown in *Figure 1*. All outlets will be equipped with a flap-valve to prevent Eastern Channel waters from entering the ponds. Outlet elevations will be set at a level adequate to allow shallow water depths to be maintained in the wetlands while preventing water from overflowing the wetland's eastern embankment during heavy rains. Outlet drains to the Eastern Channel should be placed at a higher level than the swales that interconnect the wetland area. The U-channel currently shown at the outer toe of the Eastern Channel's eastern embankment should be deleted from construction plans.

In the long term, it may be necessary to dredge out the pools and swales of the constructed wetland in order to maintain areas of open water and drainage connectivity. However, such maintenance is not expected to be required in the short term, and would be the responsibility of the authority designated as the long-term manager of the site.

4 *Revegetation*

Permanently or seasonally wet areas should be planted with sedges and rushes including *Carex* spp., *Eleocharis* sp., *Equisetum* spp., *Juncus* spp. and *Scirpus* spp. Those involved in detailed design of the site may also take note of the species proposed for ASD reedbed planting by BBV (1999). These plants will bind the soil and provide food sources for wildlife. Planted areas that die off or show unsatisfactory survival during the establishment period should be replaced by the landscape contractor, using appropriate species approved by TDD and AFD. Any additional species proposed for planting should be endorsed by AFD.

Following initial planting, these areas will also be readily colonised by freshwater or brackish-water and pioneer plant species such as *Phragmites australis, Cyclosorus interruptus, Acrostichum aureum* and the tree *Sapium sebiferum*. These plants will provide shade, shelter and breeding sites to some species and food sources for others, and natural nutrient and pollutant removal.

Fairly continuous stands of trees and bamboos will be planted at the eastern margin of the wetland along the San-Sham Road. These plantings will enhance habitat diversity and, along the San-Sham Road, will also provide a visual screen between the road and the wetlands which will block disturbance from the road and kiosk area. Such plantings will not, however, be required where the constructed wetland lies adjacent to the ASD reedbeds, as shown in *Figures 1* and 3. In such places, it may be preferable to provide a tree or bamboo border at the eastern edge of the ASD reedbeds, but this will be a matter for consideration at the detailed design stage of the two wetland projects. Tree and bamboo plantings will also provide roosting and nesting sites for ardeids and other birds; bamboos are more likely to be used as nesting sites by some species, e.g. Chinese Pond Herons, while trees will provide alternative nesting substrates and will also provide wind shelter. Tree planting will incidentally mitigate the loss of plantation trees, though this is not a top priority given the low ecological value of the existing plantations. Shrub/understory species can be planted among tree plantings at the eastern embankment of the wetland, to enhance the screening function of the plantings in the short term.

A solid row of trees or bamboo should not be planted along the eastern outer embankment of the Eastern Channel. Surrounding the site with trees on both sides would reduce its attractiveness to waterbirds that prefer an unobstructed view from their feeding areas.

However, scattered stands or clumps of trees and bamboo should be planted in the locations indicated in *Figure 3.6e* of the main report to provide additional roosting/perching sites and potential egretry sites for birds. Such plantings are indicated in *Figure* 3.6e and in *Figure 1* of this Annex by the legends "roost plantation" and "egretry plantation". Tree seedlings or whips and bamboo shoots/seedlings should be planted at 1 to 1.5 m spacings. This spacing is closer than the desired long-term spacing, to allow for non-survival of some plantings and later thinning.

The ultimate goal for all vegetated areas should be establishment of a native-species plant community. Some exotic pioneer species may however be used in planting areas in order to provide "nurse" functions for native species. Any exotic plantings are to be gradually thinned out as the native species establish.

Native species planted should focus on species which are adapted to the environment of the San Tin area. Species recommended include those found at riverine and egretry habitats elsewhere in the New Territories (Maunsell 1997), and species which are food plants for birds (Corlett 1992), butterflies (Bascombe 1993) and other insects including leafhoppers and beetles. Species recommended are shown in *Table 1*.

Table 1 *Native Plant Species To Be Used in Planting*

Scientific name	Common name	Habit
Sapium sebiferum	Tallow Tree	tree
Ficus microcarpa	Chinese Banyan	tree
Ficus variegata	Common Red-stem Fig	tree
Macaranga tanarius	Elephant's Ear	tree
Celtis sinensis	Chinese Hackberry	tree
Cinnamomum camphora	Camphor Tree	tree
Litsea glutinosa	Pond Spice	tree
Schima superba	Schima	tree
Hibiscus tiliaceus	Cuban Bast	tree
Sterculia lanceolata	Scarlet Sterculia	tree
Garcinia oblongifolia	---	tree
Bambusa tuldoides	---	bamboo
Bambusa multiplex	---	bamboo
Ardisia crenata	Hilo Holly	shrub
Ilex asprella	Rough-leaved Holly	shrub
Melastoma candidum	---	shrub
Gordonia axillaris	Gordonia	shrub
Psychotria rubra	Wild Coffee	shrub
Rhaphiolepis indica	Hong Kong Hawthorn	shrub
Rhodomyrtus tomentosa	Rose Myrtle	shrub
Litsea rotundifolia	Round-leaved Litsea	shrub
Sarcandra glabra	---	shrub

Any changes to this proposed species list should be approved by AFD. Any plants that die within the establishment period are to be replaced by the landscape contractor, using species from the same list or other species approved by TDD and AFD.

In addition to these plantings, use of standard hydroseed mixes is recommended both within plantation areas and elsewhere on the banked edges of the wetland area. This will prevent erosion, particularly during the period immediately following construction. Areas should be hydroseeded using a standard grassland mix. Hydroseeding will ensure soil stability and provide habitats that colonising species can invade. As noted above, the revegetated eastern edge of the area will also serve as a filter strip to remove nutrients and pollutants from road surface runoff before it reaches the wetland.

5 *Management Authority*

The standard one-year establishment period after completion of construction will be the responsibility of the contractor. Contractual obligations during this period will include weeding, replacement planting and other horticultural maintenance operations.

Pending the findings of the Wetland Compensation Study, maintenance and management of the constructed wetland area would be an inter-departmental responsibility of government, arranged on a model similar to that for wetland conservation sites under the Main Drainage Channels for Sheung Shui, Fanling and Hinterlands project (Maunsell 1997). Using that model, ~~the~~ maintenance responsibilities are as shown in *Table 2*.

Table 2 ***Constructed wetland area maintenance responsibilities***

Department	Responsibility
Drainage Services Department	drainage
Lands Department	lands administration
Agriculture & Fisheries Department	vegetation management

Drainage responsibilities for the short term are anticipated to include only maintenance of the outlet pipes and flap valves providing overflow drainage from the wetland into the Eastern Channel. As noted above, in the long term some dredging may be required in the wetland to restore areas of open water and drainage connectivity, but this would be a task for the long-term manager of the site.

The ongoing Wetland Compensation Study will review the existing mechanism and administrative authorities for maintenance and management of wetlands constructed, restored or enhanced primarily for conservation use. A recommendation may therefore be made upon completion of that study to shift the administrative management responsibility for this constructed wetland to another authority. The recommendations of the Wetland Compensation Study should be available well before the date of completion of this wetland area.

6 *Management*

The fundamental management objective for the constructed wetland is to minimise maintenance requirements by designing and constructing it as a self-sustaining system. This is desirable both from an ecological and a management perspective. As noted above, pumping to maintain water levels is not recommended. Stocking of fish is also considered unnecessary, as suitable species will be able to colonise the area naturally, probably within one year following completion of construction. Replacement of trees that die after the one-year establishment period is not considered to be necessary but may be undertaken at the discretion of AFD, the authority with responsibility for vegetation management in the wetland.

One management tasks will, however, be required on a regular basis: periodic removal of overly invasive species such as Water Hyacinth *Eichhornia crassipes* and the creeper *Mikania micrantha*. Weed removal should be accomplished by mechanical rather than chemical means and should be performed on a need basis as judged by AFD staff.

If periodic monitoring of the constructed wetland indicates that it is not functioning optimally, the above management measures should be reviewed and revised as necessary.

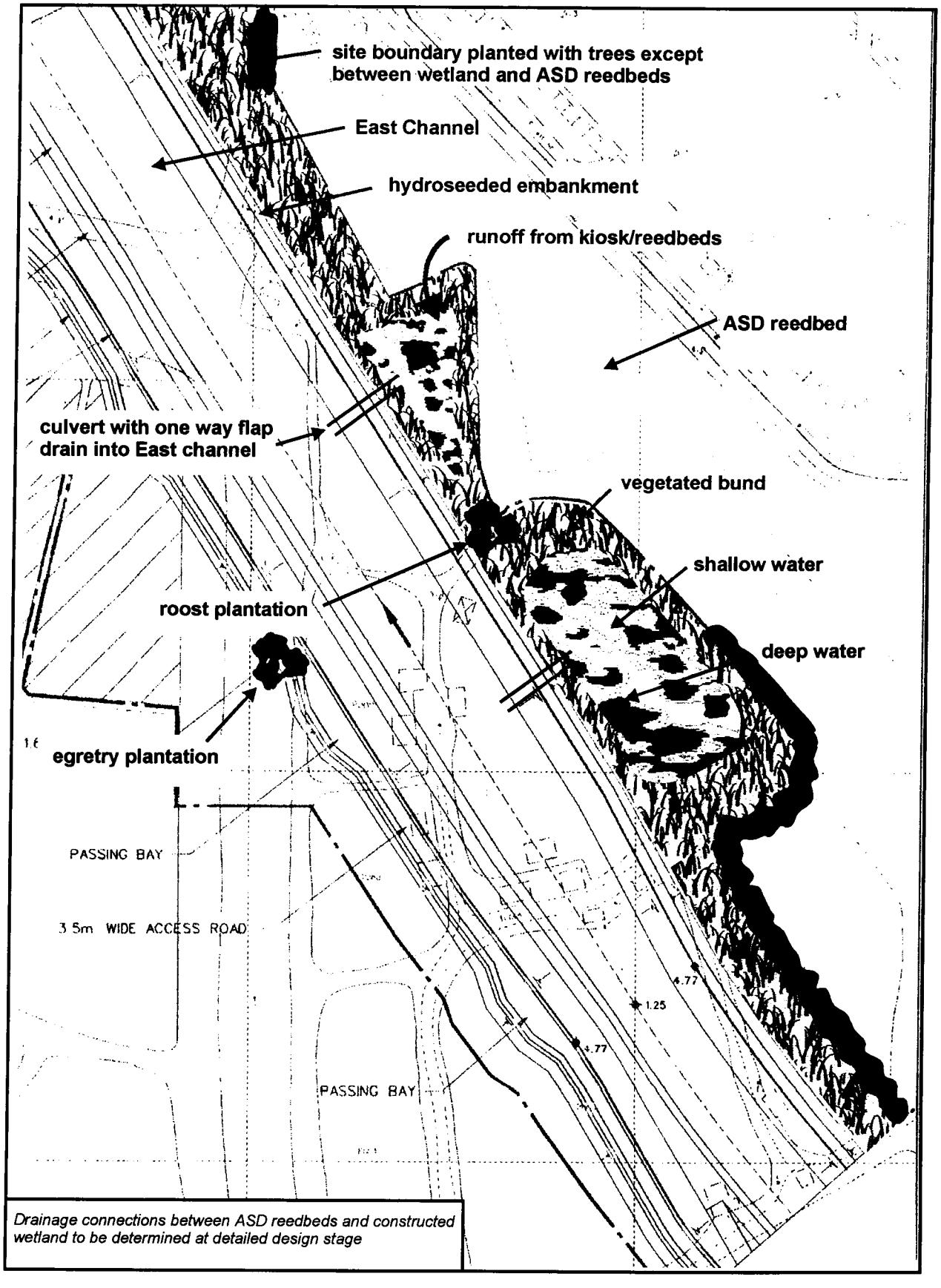

Figure 1 Schematic Layout for Constructed Wetland

NOT TO SCALE

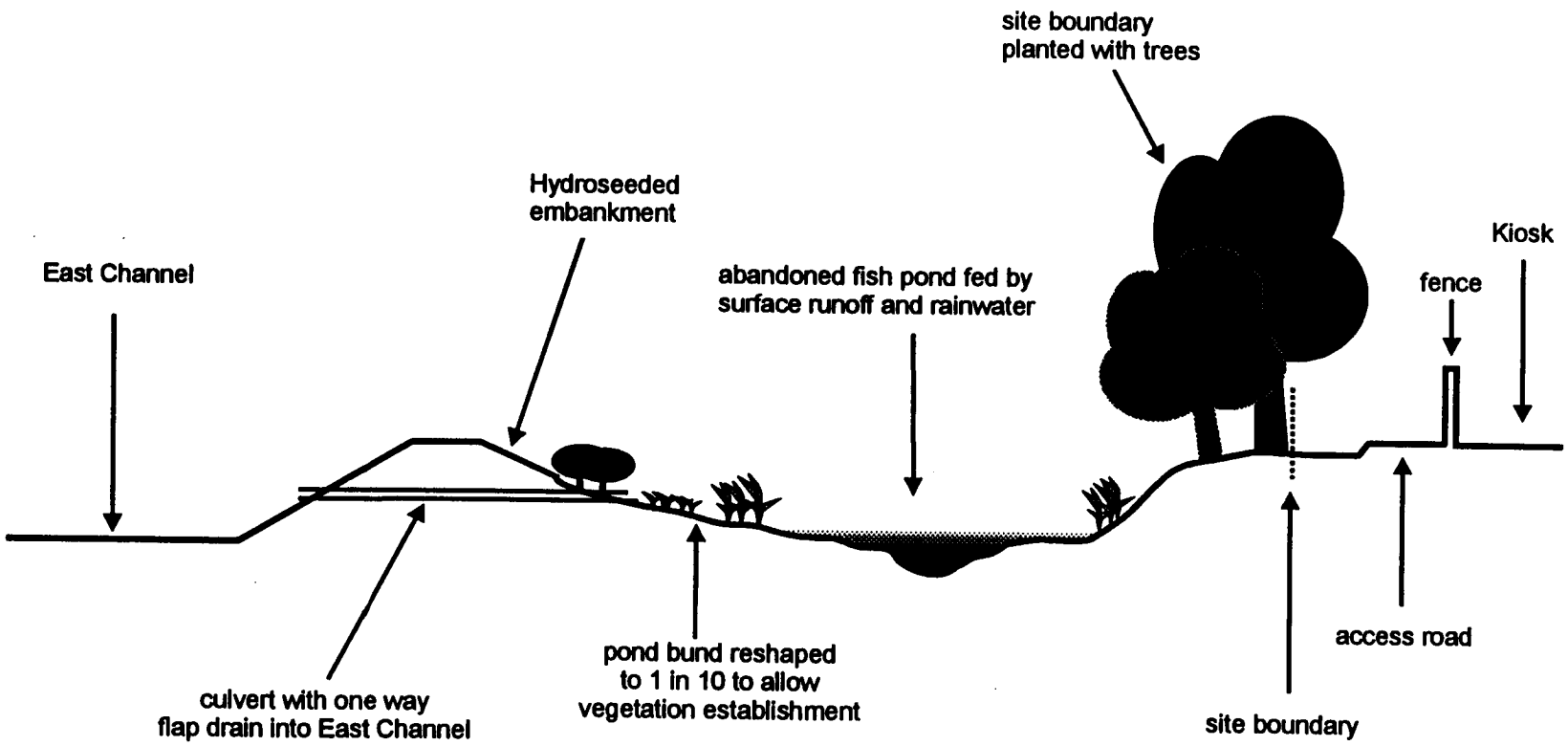

Figure 2 Typical Cross Section of Constructed Wetland

NOT TO SCALE

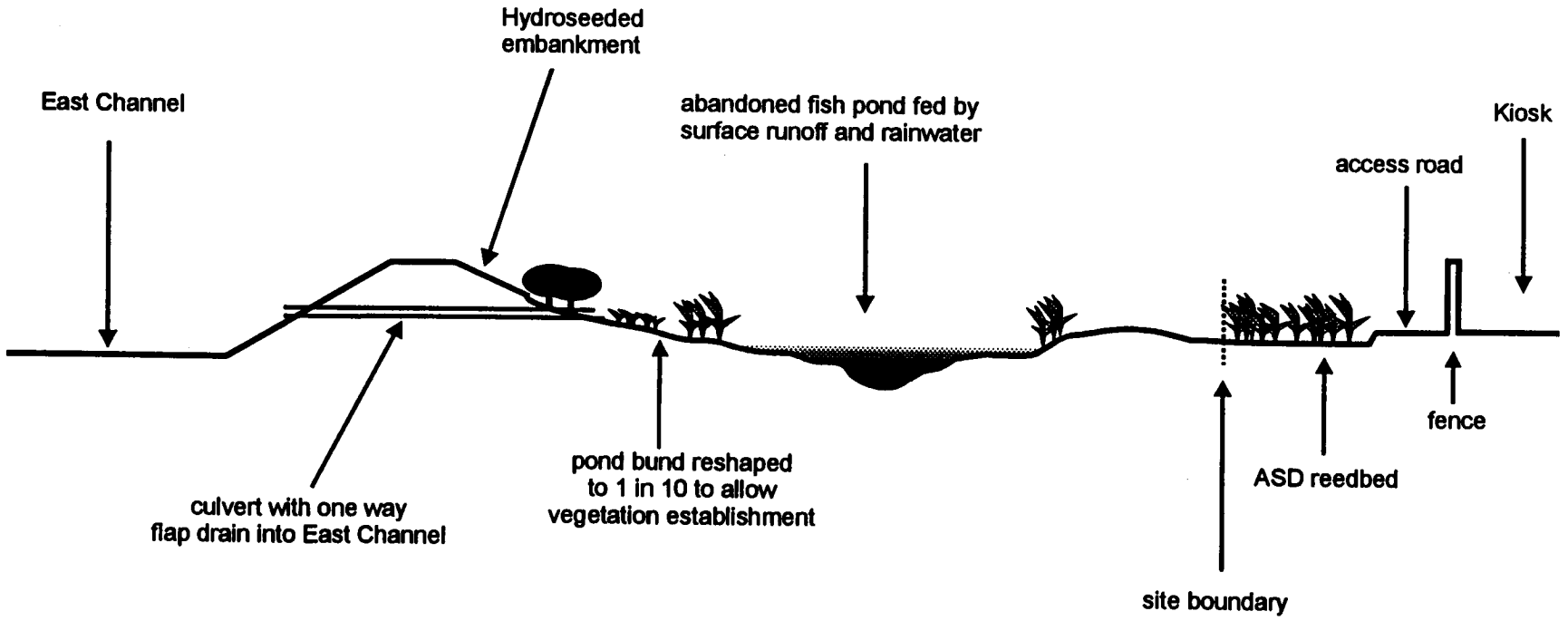

Figure 3 **Cross Section of Constructed Wetland adjacent to ASD Reedbeds**