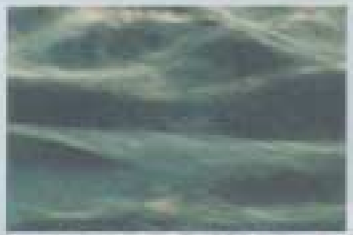
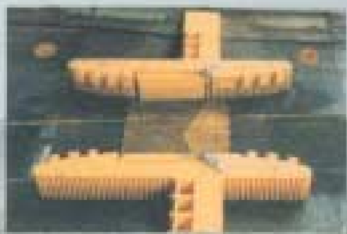


DESIGN SCHEME
FOR
HABITAT CREATION

APRIL 1997

Report No. R.584(a)



ABP RESEARCH & CONSULTANCY LTD

ABP RESEARCH

Associated British Ports

DESIGN SCHEME
FOR
HABITAT CREATION

APRIL 1997

Report No. R.584(a)

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SUMMARY

Creating new habitat or restoring previous ones can help compensate for the loss of intertidal habitat due to coastal developments. The design scheme presented in this document outlines the requirements and procedures for creating a habitat, which is based on sound scientific principles and incorporates lessons learned from previous habitat creation and enhancement schemes.

In summary, a comprehensive approach to design should entail:

(i) confirmation of the design objectives;
(ii) identification of design constraints;
(iii) characterisation of the site;
(iv) determination of target species;
(v) preliminary design;
(vi) detailed design;
(vii) field investigations;
(viii) sensitivity and risk assessment;
(ix) construction programme; and
(x) specification of monitoring requirements.

An indicative programme for carrying out the habitat design is proposed. In order to agree the design objectives and methodology, consultation with the relevant conservation bodies should be undertaken. These bodies will typically include the conservation agency (EN, CCW, SNH), RSPB[1] and the local Wildlife Trust.

The studies proposed should provide a detailed rationale for the proposed habitat mitigation, as well as providing all the information required to progress the scheme to implementation.

NOTE TO READERS

Since this report was produced in 1997, the methods set out have been extensively tested on a number of schemes. In addition, the range of tools available has developed as a consequence of several recent research initiatives. The design scheme does however, provide a useful introduction to the subject. For more up-to-date or detailed information please contact us.

[1] English Nature, Countryside Council for Wales, Scottish Natural Heritage, Royal Society for the Protection of Birds

DESIGN SCHEME FOR HABITAT CREATION – APRIL 1997

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1. INTRODUCTION

Creating new habitat or restoring previous ones can help compensate for the loss of intertidal habitat due to coastal developments. An extensive literature review has been undertaken to identify the components, which contribute to successful habitat creation schemes and to evaluate the successes and failures of previous habitat creation/restoration projects. In addition, a number of site surveys of created or restored habitats have also been undertaken (ABP, 1998).

The design scheme presented in this document outlines the requirements and procedures for creating a habitat based on sound scientific principles and incorporates lessons learned from previous habitat creation and enhancement schemes. It is important to undertake consultation with the relevant conservation bodies, to agree the scope of the scheme and particularly the design objectives.

2. DESIGN OBJECTIVES

Of paramount importance in habitat creation schemes is the setting of clear aims and objectives, which define what the scheme is actually trying to achieve. These objectives might encompass habitat connectivity, hydrological, geochemical, morphological or biological issues. Previous schemes have been undertaken with a wide range of objectives including:

- beneficial use of dredged material;
- coastal and flood defence;
- habitat development for nature conservation;
- fishery and shellfishery production;
- water quality improvement;
- ground water recharge;
- archaeological conservation.

It is important to undertake consultation with the relevant conservation bodies, to agree these design objectives at the outset of the project, since these will form the basis for assessing the success of the scheme. Typically this will include the relevant conservation agency (EN, CCW, or SNH), RSPB[1] and the local Wildlife Trust. Additionally consultees are likely to include the Environment Agency, the Ministry of Agriculture, Fisheries and Food (MAFF) and the local council and planning authorities.

For schemes undertaken as mitigation or compensation for developments, suitable aims may include:

[1] English Nature, Countryside Council for Wales, Scottish Natural Heritage, Royal Society for the Protection of Birds

- Maintenance of favourable nature conservation status for both habitats, as defined under Article 1(e) of the Habitats Directive, and species, as defined under Article 1(i); and

- Removal of any adverse effects arising from the proposed development, and to maintain site integrity (Article 6(3) of the Habitats Directive).

These aims may be broken down into the following objectives:

- To provide feeding or roosting areas for those birds using the area affected, particularly those species for which any sites are designated.

- To avoid, minimise, or offset any other impacts on the integrity of any conservation sites such as adverse effects of modified physical processes.

- To construct, as far as possible, a self-maintaining system (or systems) which can evolve in response to natural physical, chemical and biological changes.

Another aim may be:

- The conservation of features of the local conservation interest.

Again this may be broken down into a number of objectives, for example:

- To conserve a marsh as a grazing marsh; and

- To provide habitat for the nationally scarce plant species present on the development site.

3. DESIGN OPTIONS

The literature review identified a number of habitat types, which have been subject to habitat creation or restoration schemes. Options for consideration in the habitat design are presented in Table 1. The suitability of these schemes in meeting the design objectives need to be fully considered so that a preferred choice can be agreed with interested parties. The choice of option will depend on a number of factors, especially those requirements set out in the aims and objectives. However certain sites will be constrained by practical issues such as the area available for the habitat creation scheme. Furthermore, variations in baseline conditions between sites (e.g. tidal and wave levels) will mean that the most suitable option will vary between sites. Additionally, the amount of post construction management will vary between options and also for the same option undertaken at different sites.

Table 1. Options for habitat creation

Option	Information Available*	Post Construction Management
Tidal creek	Low	Low/Moderate
Intertidal mud and sandflats	Low/Moderate	Low/Moderate
Saltmarsh	Moderate/High	Low
Freshwater marsh	Moderate/High	Low/Moderate
Sluice system	Moderate	High
Saline/brackish lagoon systems	Low/Moderate	Moderate
Freshwater lagoon systems	High	Moderate
Island system	Low/Moderate	Moderate
* based on review of literature		

4. DESIGN METHODOLOGY

4.1 IDENTIFICATION OF DESIGN CONSTRAINTS

A number of physical and ecological factors will limit or constrain what can be achieved by way of habitat creation. The relevant design constraints must therefore be clearly identified at the outset. For example, in the case of tidal creek design, the following factors need to be considered:

Physical constraints:

- maximum area, length and width of site;
- potential width of creek mouth;
- sub-tidal bathymetry linking creek to main channel;
- underlying geology and lithology;
- availability of suitable surficial sediments;
- freshwater input.

Habitat constraints:

- habitat value of the development site to be compensated/mitigated for;
- habitat criteria to mitigate the effects on any conservation sites (e.g. Special Protection Area (SPA), Special Areas of Conservation (SAC);
- habitat criteria for the nationally scarce plant species on the development site;
- water quality;
- disturbance factors from operational development activities.

4.2 DETERMINATION OF SITE CHARACTERISTICS AND TARGET SPECIES

The success of the created habitat will be dependent on the existing physical, chemical and biological characteristics of the development site and adjacent environment and the requirements of target species. Much of this information will need to be obtained through field surveys, literature review, or the analysis of existing data sources (e.g. from the Environment Agency). The following sections outline the key site characteristics and the types of investigation required, Tables 2-4.

4.2.1 Sediment/Substrate

Table 2. Sediment and substrate characteristics

Parameter	Type of Investigation/Test	Uses
Vertical sediment profile to determine type of strata and sediment characteristics including: • particle size analysis • bedrock/ boulder clay levels • sediment contamination • organic carbon • shear strength for cohesive soils • ground water levels • sediment density tests	Boreholes (approx. 15 m depth). Trial Pits (approx. 2 m depth). Used in areas where depths of sediments to be removed are small and where near surface undisturbed testing is required	Determine the primary constraints on the possible degree of excavation, determination of likely ground water inputs, site material properties, degree of contamination and thus suitability for habitat creation and colonisation. Disturbed shear strengths (may be of use in replacement of excavated material).
Re-suspension criterion of nearby intertidal mudflats	In-situ shear strength testing/ shear vane • shear vane testing or portable carousel methods	Gives information for modelling of sediment transport mechanisms at site for fine materials
Sediment consolidation	Oedometer tests or Rowe cell tests	Over/under consolidated results will yield predictions of relaxation after excavation. Long term consolidation at site
Replacement material characteristics (optional)	Particle size, contaminants, organic content	Provide information on the material that will form part of the habitat. (Only if replacement material is to be used)

4.2.2 Hydrodynamics, Hydrology and Morphology

Table 3. Hydrodynamic, hydrological and morphological characteristics

Parameter	Type of Investigation/Test	Uses
Type and quantity of sediment material deposited seasonally	Sediment traps	To determine likely sediment deposition rates within neighbouring intertidal areas on a seasonal basis. This would aid in the calibration of the sediment transport model and in the determination of degree of sediment supply and deposition at the site
Levels of suspended sediments in the adjacent areas	Turbidity test • suspended sediment sampling • continuous recording current meter, siltmeter • Acoustic Doppler Current Profiler (ADCP)	As above
Intertidal stream velocity measurements (for the intertidal calibration of the hydrodynamic model)	Deployment of continuous recording current meter, silt meter, salinity probe on bed frame, bed mounted ADCP	Aid in the calibration of the model of hydrodynamic flows within neighbouring intertidal areas. Such relationships may then be compared with those predicted at the proposed site
Location of aquifers and discharges, and volumes of freshwater input	Freshwater runoff and ground water measurements; meteorological assessment	Determine the likely freshwater volumes entering the site and consequently the salinity levels at the site. Testing of runoff water should yield contaminant levels and also likely sediment inputs
Water chemistry	Salinity, dissolved oxygen, turbidity, temperature measurements	Determine the physical parameters aquatic flora and fauna will be subjected to
Water quality including nutrients, bacteria, heavy metals, polyaromatic hydrocarbons and pesticides	Review Environment Agency data; water quality sampling to determine contaminant levels where necessary	Determine the factors which could effect establishment and growth of flora and fauna

4.2.3 Habitat and Species

Table 4. Habitat and species characteristics

Parameter	Type of Investigation/Test	Uses
Nutrient and organic carbon accretion rates seasonally	Sediment traps	Determine likely amounts of nutrients and organic material, which will be available to colonising species
Target species: Benthic microbes	Sediment analyses	Identify existing microbial populations so that their habitat requirements can be incorporated into the design
Target species: Phytoplankton (seasonal variation)	Environment Agency data analysis; possible phytoplankton monitoring	Identify the existing potential primary colonisers so that their habitat requirements can be incorporated into the design
Phytoplankton habitat requirements	Literature review including tidal inundation, salinity, shelter, sunlight	Determine the habitat requirements to support identified target species
Target species: Benthos	Data analysis of composition, abundance and diversity of aquatic benthic communities	To identify the existing species which are likely to colonise the new habitat; assess the existing benthic value of the site
Relative densities and distribution of benthos	Data analysis of benthos	Provide information on bird feeding criteria
Benthos habitat requirements	Literature review including tidal inundation, submergence, shelter/exposure, tidal scour, salinity	Determine the habitat requirements to support identified target species
Benthic colonisation rates	Existing data analysis	Provide essential information regarding the periods of time necessary for development of benthic communities able to provide food for wading birds

Table 4. Habitat and species characteristics (continued)

Parameter	Type of Investigation/Test	Uses
Target species: Fish	Existing data analysis	To identify the existing species which are likely to colonise the new habitat and which would provide food for birds
Fish habitat requirements (adult, juveniles, spawning grounds)	Literature review including tidal scour, shelter, salinity, oxygen, water depth, water exchange, vegetation cover, elevation, topography	Determine the habitat requirements to support identified target species
Target species: Vegetation	Site survey; mapping, soil sampling	Identify existing species, which are likely to colonise the new habitat and determine their proximity to the site; determine the present supporting substrate
Propagation strategies	Literature review including germination time and season	Determine the reproductive potential and requirements for identified target plant species
Vegetation habitat requirements	Literature review including elevation, tidal inundation, submergence, shelter/exposure, tidal scour, salinity, waterlogging	Determine the habitat requirements to support identified target species
Weed species identification	Site survey	Determine whether any species which exist in the area are likely to dominate the site to the exclusion of target species
Target species: Overwintering birds	Bird counts	Determine numbers and species of birds
Bird feeding/migratory requirements	Literature review including topography, exposure, preferred prey species, disturbance factors	Determine the habitat requirements to support identified target species
Patterns of feeding distribution	Bird marking and observation	Provide information on the patterns of bird use at different tidal states and seasons
Target habitat: Buffer zone	Site survey	Evaluate the area and characteristics at the site, which will form the buffer zone

4.3 PRELIMINARY DESIGN AND INVESTIGATIONS

The preliminary design of the created habitat will be based on the hydraulic and morphological criteria and ecological requirements as defined in the previous tasks.

4.3.1 Hydraulic and Morphological Design

The hydraulics and morphology of the various design options are closely inter-related. The most complex is a creek system. The design method, therefore, sets out the steps to develop a creek design. All other options would make use of a sub-set of these steps. In most cases the hydraulics and morphology can be characterised in terms of tidal discharge or prism, against widths, depths, cross-sectional and plan areas. An iterative process should be used to characterise the hydraulics and morphology of the design option:

- define total and intertidal plan areas;
- use hypsometric relationships (O'Brien, 1931; Renger and Partenscky, 1974; Boon and Bryne, 1981) to determine the approximate size for the creek option;
- use of analytical models to examine discharge/morphological regime (Leopold and Langbein, 1962; Langbein, 1963; ABP, 1996a and 1996b);
- fit design option into surrounding topography;
- examine suitability of habitat for flora and fauna and in a landscape context;
- iterate as required.

4.3.2 Ecological Design

The ecological development of the site is dependant on providing suitable habitat conditions for the target species and involves an iterative process with the hydraulic and morphological design of the site to attain these conditions. The ecological design should be developed as follows:

- define diet requirements of bird species whose habitat is to be mitigated/compensated;
- define total area and intertidal area required for long-term support of bird species whose feeding habitat requires mitigation/compensation;
- determine the appropriate intertidal elevation to provide a tidal inundation regime for the provision of habitat for sufficient development of typical benthic prey species;
- use saltmarsh colonisation/tidal range/effective fetch relationships (Gray, 1992; Chapman, 1960) to design appropriate intertidal elevation to prevent the encroachment of the intertidal flat by pioneer saltmarsh species which would reduce the habitat value for feeding bird species;
- assess range of gradients suitable for provision of the required area of intertidal flat and that for saltmarsh development based on recommendations given by Woodhouse (1979), Zedlar, (1984), Knutson, Allen et al (1990);
- determine the range of intertidal gradients appropriate for use and access by feeding bird species;

- define suitable soft sediment types for the colonisation and development of prey communities in terms of their composition, consolidation, organic content, contaminant levels;
- identify freshwater/salinity and water quality conditions preferred/tolerated by main invertebrate prey species;
- integrate created habitat with existing and retained habitats, to include an ecological transition from intertidal flats to upper saltmarsh communities;
- examine the potential use of ancillary habitats to enhance overall habitat value and diversity;
- examine habitat suitability in landscape context;
- iterate for possible habitat enhancement opportunities as required.

4.3.3 Modelling

Once an outline layout (or set of options) has been agreed, some preliminary modelling can be used to examine the hydraulics of the site in more detail. This seeks to establish the local and short term response of the design option(s) and also the neighbouring estuarine system and should proceed as follows:

- establish boundary conditions for numerical model;
- set-up model to cover adjacent reach of estuary and proposed development;
- validate model without the development and mitigation, against hydraulic and sedimentological site measurements taken over existing intertidal area;
- introduce the development and mitigation and examine tidal stage (including any asymmetry), tidal residuals, slack water periods (Dronkers, 1986), bed shear stresses and tidal energy transmissions. This investigation includes tides and also wave/tidal current interaction;
- examine impacts on the adjacent estuary waters and adjust mitigation design to minimise impact (e.g. for the creek option: cross-estuarine jetting flows, residual eddies/gyres, etc);
- carry out a series of sensitivity tests to examine the impact of adjusting key dimensions (e.g. mouth width, creek length, number of sub-creeks, sinuosity of main and sub-creeks);
- refine layout in conjunction with ecological requirements.

4.4 EXPERIMENTAL FIELD INVESTIGATIONS

Following completion of the preliminary design and modelling investigations, field investigations will be needed to collect information to complete the scheme design and to resolve any remaining uncertainties. There are a number of specific areas, which may require further clarification, especially those features, which are highly site and scheme specific. A review of the literature indicates that it is these features which have been poorly studied in previous habitat creation schemes. These features include:

- sediment salinity in response to tidal flushing;
- rates of sediment consolidation;
- rates of sediment accretion, siltation in ebb or flood dominant systems;
- sedimentation rate in response to changes in accretion/erosion and tidal flushing;
- rates of colonisation of algae, benthos and plants;
- influence of sediment organic content or water salinity on colonising floral and faunal species;
- buffer zone requirements;
- bird uses of enclosed intertidal habitats where sight lines are restricted;
- the effects of noise and lighting on bird feeding patterns.

Additional investigation of natural intertidal flat and creek systems in the region may be required in order to provide further information on the ecological use of such habitats, such as the range of intertidal gradients and elevations over which wading bird species feed.

4.5 DETAILED DESIGN OF CREATED HABITAT

The detailed design phase will need to consider the short and long term physical and ecological operation of the mitigation in both a local and estuary wide context, in addition to the monitoring and possible maintenance requirements of the created habitat. The detailed ecological design and numerical modelling should be based on the information gathered during the preliminary design stage and the field investigations.

4.5.1 Short Term Considerations

The short term considerations can be investigated with the aid of a fine grid numerical model of the site, which incorporates waves, tides, sediment transport and water quality (particularly salinity predictions). The approach should be as follows:

- set-up of a local fine grid model nested within the existing estuary model;
- incorporate fresh water flows from the landward run-off/ground water and any local discharge points (note: for the tidal creek option these may be significant and require a dendritic form to the upper creek to collect and channel the water into the main creek channel);
- model sediment transport for all relevant particle size fractions and establish the patterns of short term morphological evolution;
- examine flushing characteristics and in particular the salinity distribution within the mitigation;
- incorporate ecological requirements into the design including tidal influence, intertidal elevations, topographic gradients and suitable substrate;
- develop predicted profiles of the ground water levels at the land/intertidal interface;

- iterate to establish acceptable balance between ebb/flood dominance, suitable flushing and salinity characteristics, and flow rates amenable to the desired balance between mudflat and vegetated areas.

4.5.2 Long Term Evolution

The long term evolution of the mitigation and the estuary as a whole can be considered as follows:

- set up an entropic model of the creek to iterate system bathymetry to a quasi-steady state. Such tools have been developed to determine the long term evolution within the estuarine system (ABP, 1996b);
- examine options to construct the mitigation to match the steady state form, or the timescale for it to evolve from other forms (which may be preferred for other design considerations e.g. suitability for rapid colonisation);
- map creek into estuary system and use entropic model to examine how the estuary as a whole will adjust to this new feature (this will interact with the berth and dredging layout and some co-adjustment may be appropriate to optimise the design and minimise long-term impacts of the development as a whole);
- ensure feasibility of development and eventual stability of the ecological features when considered with respect to the physical design of the created habitat to provide long-term habitat for wading birds.

It is important to identify the existing morphological behaviour of the proposed habitat creation site, since it may be possible to offset some of the negative changes, which are occurring naturally. For example, if the existing foreshore habitat is known to be eroding and is constrained to landward by the existing reclamation, future sea level rise would exacerbate this, thereby reducing its habitat value. However it may be possible to design the mitigation to adjust to accommodate changes in sea level.

The above studies can therefore usefully be extended to include a sensitivity analysis, concentrating, in particular, on the response of the system to sea level rise.

4.5.3 Construction Programme

The detailed design of the scheme should provide a sound and comprehensive programme for construction. This needs to include consideration of the following:

- identification of critical and sensitive biological periods of flora and fauna in which to avoid construction, such as breeding seasons;
- identification of seasonal and tidal periods which provide the optimal physical conditions for the construction of the intertidal system and its initial development;
- determination of the period of time required for the development of the newly created habitat;

- strategies to minimise adverse affects on existing and newly created habitats during the construction phase which may involve special requirements for rare or notable species.

4.5.4 Monitoring and Maintenance

Monitoring is an essential part of any habitat creation scheme, enabling the evaluation of whether objectives are being met, whether there are any impacts on the surrounding environment and, ultimately, the success of the scheme. In order for an ongoing assessment of the success in establishing the scheme, the monitoring programme should include a definition of what is to be monitored and what constitutes satisfactory performance in meeting the design objectives. The definition of the monitoring timescale and performance should take into account the different timescales associated with the individual objectives. The specification of such a post-construction monitoring scheme should be undertaken as part of the design stage. The design plan will also include a contingency plan (Article 6(4) of the Habitats Directive). This needs to contain the details of alternative mitigating options, to be put into effect if the design objectives are not met within the defined timescales.

5. RISK ASSESSMENT

The evolution of an ecosystem is a dynamic process, and it is not always possible to predict and control the external factors, which direct its development. This is particularly true of intertidal habitats as these are subject to complex coastal processes as well as anthropogenic disturbance and have natural boundary constraints.

Innovative designs may involve a high degree of development. Sensitivity studies are therefore essential if a proper understanding of the uncertainties in such schemes are to be established. Careful consideration of these uncertainties should be an integral feature of the design process in order for the risks to be evaluated and managed. The assessment of risk needs to examine both the likelihood of the designed habitat establishing itself and the ability of this habitat to adequately mitigate for what is being lost.

6. CONCLUSIONS AND RECOMMENDATIONS

From the review of the available literature case studies, it is clear that a great number of intertidal habitat creation schemes have been undertaken with varying degrees of success. These have included saltmarsh, intertidal mud and sand flats, lagoon systems, islands and tidal marsh systems. Failures have often been attributed to poorly developed designs, which have not considered all the features necessary to achieve the desired objectives. Whilst documented schemes have addressed certain components, few, if any, have considered the contributory effects of all the components at the design stage. This document has therefore sought to draw together our own design knowledge, with the broader range of experience documented in the international literature to set out, in some detail, the steps required. In summary, a comprehensive approach to the design should entail:

(i) confirmation of the design objectives;
(ii) identification of design constraints;
(iii) characterisation of the site;
(iv) determination of target species;
(v) preliminary design;
(vi) detailed design;
(vii) field investigations;
(viii) sensitivity and risk assessment;
(ix) construction programme; and
(x) specification of monitoring requirements.

These aspects of the design process are shown on the design flow chart (Figure 1).

An indicative programme for the habitat design is shown in Table 5. Steps (ii) to (v) above are required to arrive at a more detailed conceptual layout that meets all aspects of the objectives. These steps will, therefore, need to be progressed before mitigation proposals can be meaningfully discussed with relevant consultees. Further consultation with interested parties is recommended at this juncture to agree the preliminary design. The remaining steps, (vii) to (x), will establish a detailed rationale for the proposed habitat mitigation. This should provide all the information needed to progress the scheme forward to implementation.

Table 5. Mitigation design approach task list

Number	Task
1	**Identify Design Options**
1.1	Agree design aims and objectives
1.2	Identify design constraints
1.3	Consider habitat options
1.4	Consultation with interested parties
2	**Characterise Site**
2.1	Hydrodynamics/hydrology/morphology
2.2	Habitats and species
3	**Preliminary Design**
3.1	Hydraulic and morphological design
3.2	Ecological design
3.3	Numerical modelling
3.4	Consult on preliminary design
4	**Detailed Design**
4.1	Model short term behaviour
4.1	Model long term evolution
4.3	Prepare construction programme
4.4	Devise monitoring programme
4.5	Sensitivity and risk assessment
4.6	Detailed design report

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FIGURE

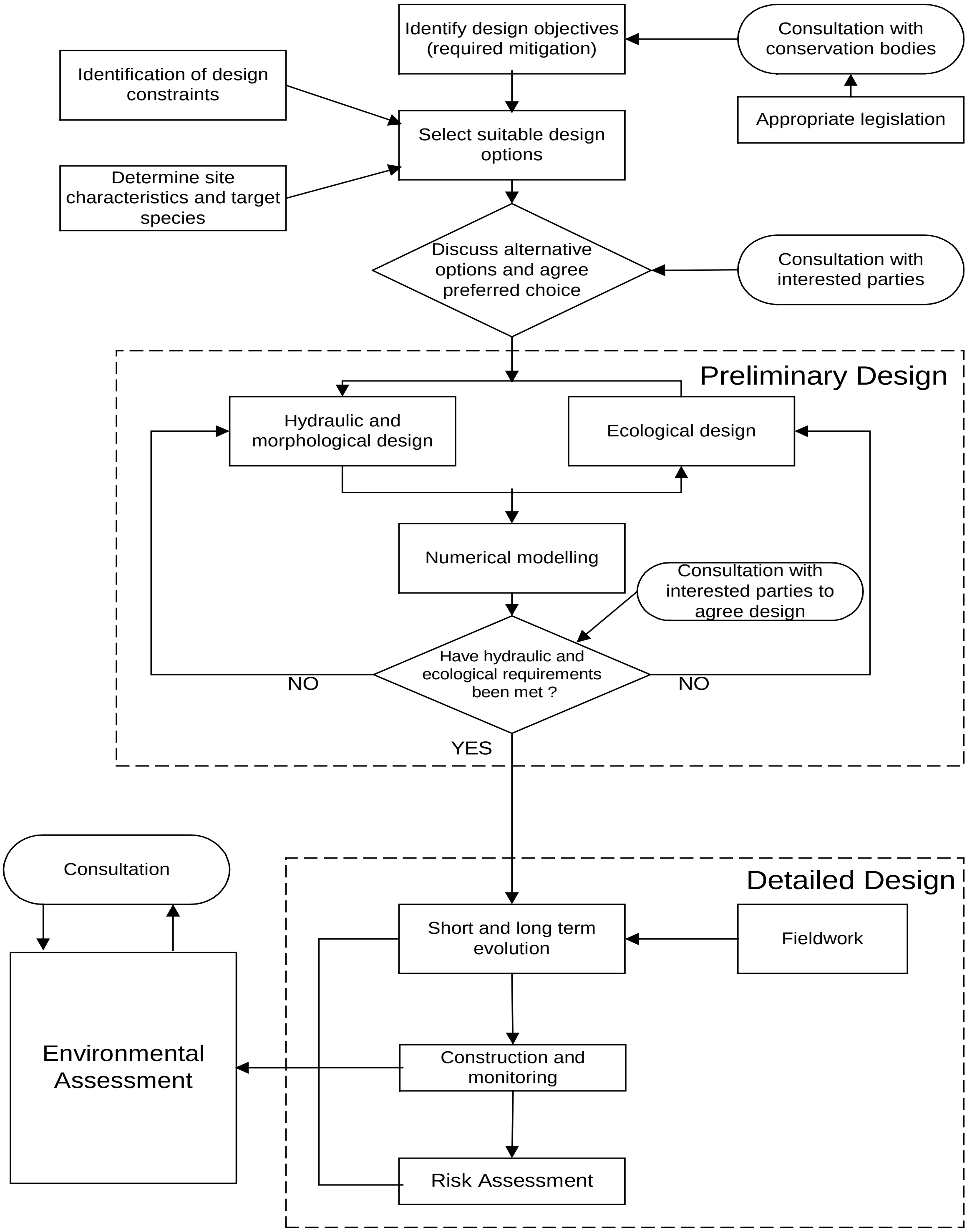
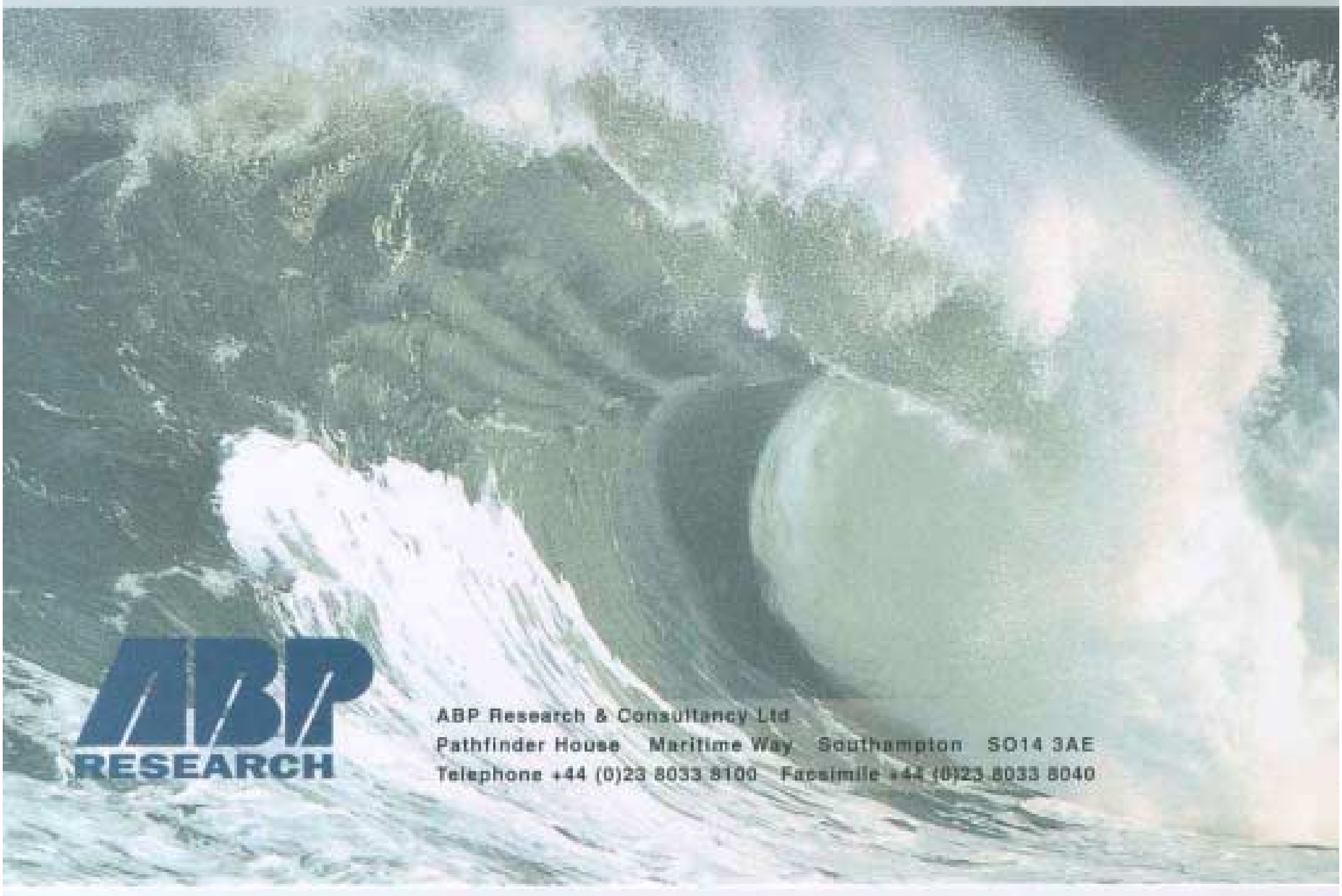


Figure 1. Design Flow Chart for Habitat Creation



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