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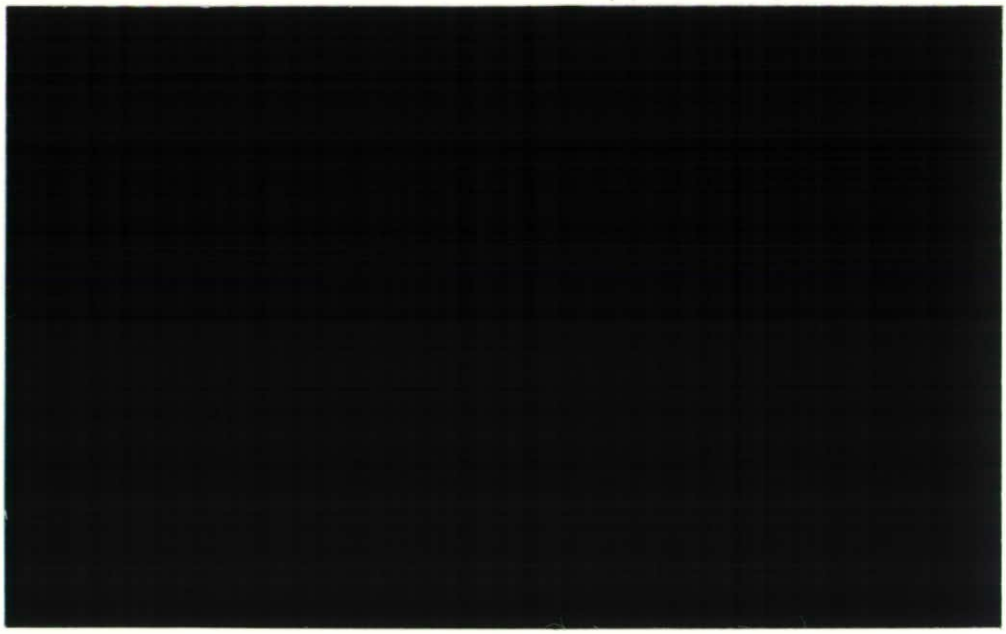

Natural Environment Research Council

Evaluation of Feasibility Study Report

"Cardiff Bay Barrage - Creation of wetlands at Redwick"

(Mason Pittendrigh)

Report from IH to CCW

Contract no. FC 73-01-61

Kevin Gilman MA MIWEM

Institute of Hydrology
Staylittle
Llanbrynmair
Powys
SY19 7DB
UK
Tel: 05516-652
Fax: 05516-441

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1. Background

The construction and operation of the Cardiff Bay Barrage will lead to the loss of intertidal mudflats of the Taff-Ely SSSI, an important feeding ground for wading birds. The Cardiff Bay Development Corporation (CBDC) has accepted that mitigation measures will form part of the final scheme, but an initial proposal to provide alternative feeding grounds by creating an artificial intertidal lagoon was turned down by the House of Commons Select Committee. The proposal now under consideration is to re-create wetland habitat on an area of about 650 acres of reclaimed marshland at Redwick (centred on grid reference ST405837).

In June 1992, CBDC commissioned a consortium of consultants, headed by Mason Pittendrigh, to prepare a report on the feasibility of the alternative proposal. A copy of the final draft report, presented in December 1992 (Mason Pittendrigh 1992)[1], was made available by the Countryside Council for Wales (CCW) to the Institute of Hydrology (IH). IH was commissioned by CCW to prepare an assessment of the hydrological aspects of the Feasibility Study report, to assist CCW in reaching its own decision on whether to accept the proposed compensation measures. This report addresses the three requirements imposed by the CCW contract:

i) *to assess the methods employed by the consultants to meet the hydrological aims of the Feasibility Study to create the desired wetland habitats at Redwick*

ii) *to assess the interpretation of the hydrological data (including water quality) by the consultants in relation to the aims of the Feasibility Study.*

iii) *to comment critically on the validity of the conclusions reached by the consultants on the possibilities for wetland habitat creation at Redwick.*

2. The Feasibility Study Report

In addition to Chapter 5 (Hydrology), which encompasses most of the material under review by IH for CCW, the Feasibility Study Report contains three other chapters which deal with hydrological issues in passing, or rely on conclusions drawn from the work in Chapter 5: Chapters 3 (Environmental), 4 (Geology) and 6 (Environmental design). It is appropriate to start with an evaluation of Chapter 5, and then to move on to the other Chapters. Comments will be focussed on the arguments in the Report, and the conclusions drawn, rather than on the facts.

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[1] Mason Pittendrigh (1992) Cardiff Bay Barrage - creation of wetlands at Redwick, Feasibility Study Report to Cardiff Bay Development Corporation, Final draft (excepting Appendix 4) seen by KG.

2.1. CHAPTER 5 - HYDROLOGY

Page 5.1, Section 5.1:- The chapter opens with a quotation from two eminent US exponents of the creation of artificial wetlands, emphasising the central importance of hydrology. This introduction encapsulates three important principles which should direct the design of the Redwick scheme, and are a suitable basis on which to judge its likely success:

i) the ecological structure of wetlands depends to a large extent on the variation of water levels on daily and seasonal timescales

ii) successful wetland design and management depends on a thorough understanding of natural systems

iii) the designed wetland should incorporate a variety of hydrological regimes and, while stable overall, should illustrate the successional states along the hydrosere.

Page 5.1, Section 5.2:- The geology of the site is very simple, showing little variation from the theme illustrated on Page 4.2. The Mercia Mudstone Group (Keuper Marl) is overlain by gravel, and a thick layer of estuarine silty clay with some peat lenses. The upper part of the profile consists of desiccated silty clay, which is drained by field drains to the reen system. Perhaps surprisingly, there is no peat at the surface.

Page 5.3:- It is clear from Section 5.3.1 & 5.3.2 that the management of the reen system is firmly in the hands of two bodies, the National Rivers Authority (NRA) and the Internal Drainage Board (IDB). Neither of these organisations is likely to make substantial changes to its policies with regard to the operation of the arterial system, and the wetland creation scheme will have to work within this framework.

Page 5.5:- A more worrying aspect of water level control (Section 5.3.2.3) is the absence of data on the day-to-day operation of (presumably the IDB) sluices. Coupled with the admitted total lack of records on flow rates, this points to a serious lack of knowledge about present hydrological conditions in the reens. Because of the timescale of the study, there was little that could be done to collect data on reen flows, but it is unfortunate that ignorance appears to extend to the catchment area as well: this may be due in part to complications in the drainage system upstream of the proposed reserve.

Page 5.7, Section 5.4.2:- While the recent increase in evaporation rates may not signal a long-term change, the created wetland must be designed to be sustainable through a comparable period. It is appropriate for this purpose to make the conservative assumption, and to work with the 5-year rather than the 30-year average.

Page 5.8:- The "capital volume" mentioned at the start of Section 5.5 is the amount of water required to fill the system in question, i.e. the capital volume for a pool of 15 ha area and 0.5 m depth is 15 x 10000 x 0.5 = 75000 m^3. The Report distinguishes between the capital volume, which is required once only, within the first few years of the scheme, and the water supply required to maintain the various wetland types in perpetuity. This water supply is calculated from an approximate water budget, based on simple assumptions and a very limited amount of data.

Page 5.11:- The consultants are correct in assessing the literature on wetland transpiration as "confusing", and their conclusion is probably the best that can be reached under the circumstances. Having said this, the list of references quoted (Page 5.14, Table 5.2) is an inadequate sample, and for the most part contains only papers written at a time when the instrumental development of hydrometeorology was limited. It is unfortunate that they did not have access, for instance, to the literature survey by Crundwell (1986[2]), who reviewed a large number of papers and came down on the side of increased evaporation by emergent plants (compared with open water at the same location). They have not drawn attention to the fact that many, if not most, of the studies have been undertaken in continental climates, or even in semi-arid regions where the "oasis effect" is significant. This could account for some of the very high evaporation rates recorded. The figure of 1.3x enhancement is not unreasonable for reeds in standing water, and is probably conservative for mixed and less tall communities. It was quite proper under the circumstances to add the caveat at the top of Page 5.12.

Page 5.12:- The concept of soil moisture deficit (SMD) has been used to give an estimate of the amount of water required to "wet up" summer-dry soils to provide saturated ground as a starting point for filling up the wetland areas. Again a conservative estimate has been used: a "potential" SMD based on potential evapotranspiration over the last 5 years, and a starting point for the filling operation in late summer. The SMD calculation provides an amount which is added to the required capital volume for each habitat.

Page 5.14:- The water budget calculation, on which is based the requirement for a water supply for the maintenance of the system, is rudimentary (Tables in Appendix 6.2).

i) no account is taken of vertical or lateral seepage out of the wetland areas and water bodies which are elevated above the reen system

ii) the seasonal water budgets are based on the 5-year mean, which is quite conservative, but there has been no attempt to explore the budget for a really extreme year or sequence of years, as would normally have been the case in a water resource evaluation.

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[2] Crundwell M E (1986) A review of hydrophyte evapotranspiration, *Rev. Hydrobiol. Trop. 19(3-4),* 215-232.

iii) no calculations are presented to justify the size of reservoir storage on site, or the consequences of opting for a different storage volume. Anticipated drawdown of the reservoir surface is an important consideration for the conservation value of the open water areas, and this has not been taken into account.

iv) the option of whether additional water supply is required temporarily or in the long term is being left open, presumably in the hope that there is a slight annual surplus of 14296 m^3, as in Appendix 6.2(d). However, this surplus, which amounts to less than 1% of the annual rainfall input, would be eliminated by just 8 mm of vertical seepage or an increase in the reedbed evaporation enhancement factor from 1.3 to 1.35.

v) no allowance has been made for surface outflow from the system. The reservoir may be inadequate to provide capacity for high rainfall inputs, which will generate surface runoff from the site. The maintenance of a relatively constant water level across the site is most economically achieved by routing a continuous outflow over weirs, and water quality objectives are best served by building a degree of flushing into the design.

Page 5.16:- Note that both pH and dissolved solids content (as indicated by conductivity) of the Great Spring are quite high. The conductivity is higher than that of about half of the reen samples, though in the case of the Great Spring calcium bicarbonate rather than sodium chloride may be responsible. In any event reen water conductivities could be expected to be higher than average in August, owing to evaporation and the greater proportion of water being supplied by seepage through calcareous soils. It is possible that the use of Great Spring water on site, and allowing it to overflow or seep into the reen system, would bring about changes in the ecology of the reens. This is an important point as the Great Spring is the source of water supplied to Whitbreads, and Whitbreads treated effluent may be similar in overall quality.

Page 5.17:- The "commercial confidence" understanding arrived at with Whitbreads means that it is completely impossible for an outsider to assess the feasibility of using this supply of water to the site. We are being asked to accept, without evidence, the consultants' assurance that "water quality requirements can be accommodated by reedbed treatment". There are three main questions which are not answered at all by Section 5.6.2.4:

i) does the Whitbreads effluent differ significantly in its major ion composition from the water that presently maintains the reen habitats on the SSSI? If so the change in base status resulting from the development of the wetland site could seriously affect the reens.

ii) what quality criteria are being used for an acceptable water supply to the site? Establishing present conditions, including seasonal variations, and deciding whether it is necessary to equal or better these in future, would have required

a more extensive study than could have been accomplished between June and November, but the Report should have included some guidelines.

iii) effluent treated by conventional means can be very high in dissolved nutrients. What is the basis for the assertion that 2 ha of artificial reedbed will be sufficient to strip these from the supply, how long will each bed be able to fulfil this function satisfactorily, and how much expense will be incurred by the operators of the site in the long term?

Page 5.18:- The design of reedbed treatment plants, which relies on flow through a permeable root zone incorporating a mosaic of aerobic and anaerobic conditions, requires careful control of water levels and velocities, so as to avoid short-circuiting. In view of the seasonal variations in the demand for water, and in the uptake of nutrients by micro-organisms and the emergent vegetation, it is difficult to see how a dynamically fluctuating system, with a measure of uncontrolled, "natural" behaviour, could provide the necessary consistent and reliable removal of nutrients from the water supply.

Page 5.20, Section 5.7.2.1:- While there is little that can be said about the nitrate results in Table 5.3, the phosphate concentrations in the reen system are high enough, with the possible exception of samples 1 to 4 and 19, to indicate some runoff of applied fertiliser. It is unfortunate that the map (Appendix 5.5) does not give the exact positions of sampling points, so it is not possible to attribute high inputs of phosphorus to particular reens. However, it does appear that the low phosphate levels in the northwest of the site could be associated with lower fertiliser application rates on the low-lying and presumably wetter part of the site.

Page 5.20, Section 5.7.2.2:- The problem with conductivity, not addressed here, is that in natural waters it is generally an indicator of either sodium chloride or calcium bicarbonate. At Redwick, although sodium chloride is certainly a contributor to the electrical conductivity, it may not be the sole determinand, and it is misleading to make a direct conversion to sodium chloride levels as in Table 5.3 (see 1st paragraph on Page 5.21). How much more informative it would have been to carry out major ion analysis on these samples!

Page 5.22, Table 5.4:- Water in trial pits has seeped from the interstices of the silt, and has had the opportunity to reach equilibrium with the matrix. Moderately high conductivity in this context suggests either a significant calcium carbonate component of the silt (see Section 5.8.1), or residual marine salts and a low permeability.

Page 5.23:- Data from the trial pits are consistent with the geological interpretation, though of course the full depth of the estuarine clay is not proved. The blue-grey silty clay is similar to and probably contemporary with that underlying the Somerset Moors, but peat development was patchy and short-lived at Redwick, and alluvial mineral sediments were laid down in this more active environment.

Page 5.26, Section 5.9.1:- The water budget calculation has not demonstrated beyond reasonable doubt that a wetland system could be sustained here. The maintenance of the wetland depends upon a surplus of water being available after the demands of increased seepage (induced by elevated water bodies, but moderated by ground surface treatment) and increased evaporation rates (by increased aerodynamic roughness and elimination of the SMD control on transpiration) have been set against the excess winter rainfall, which would have run off but will be stored in the reservoir. It has been shown above that this surplus is debatable.

Page 5.26, Section 5.9.1:- The quantity of water available from the Whitbreads outfall is certainly sufficient, but there is a question mark over its suitability on quality grounds (see above).

Page 5.27, Section 5.9.2:- Using subsurface land drains for sub-irrigation, though possible, is very doubtful where flows are uni-directional, owing to sediment build-up, both in the drains and in their surrounding permeable backfill. However, this scheme may look to sub-irrigation only in its very early phase, to wet up subsoil, close cracks and reduce subsequent seepage, and clogging of the tiles will not be a problem.

Page 5.27, Section 5.9.2:- Sedimentation in reens will continue to be a problem, and a cycle of maintenance will need to be established. Presumably the main reens, now under the control of the NRA and IDB, will be maintained on the present timescale, which seems to be congenial to SSSI-quality ditch flora and fauna, but disposal of sludge (probably rich in phosphorus) will have to be carefully arranged to prevent eutrophication of the larger areas of open water. Ditch maintenance will feature as a significant item of on-going expenditure for the site operators.

Page 5.28, Section 5.9.4:- The important question of the size of reservoir required to catch floodwaters on site is left to the detailed design stage. Nevertheless it should be noted that every cubic metre of water shed to the reen system under high rainfall conditions will have been lost from the annual water budget of the site, and will have to be replaced from an external source. At the design stage there will be a balance to be struck between the size (and hence the expense and loss of useful wetland habitat rather than open water area) of the reservoir, the acceptable drawdown of its surface (too much water level variation will stress marginal habitat, reduce the usefulness to water birds, and diminish aesthetic value), and the cost of imported water.

Page 5.31:- This has been a feasibility study, carried out on a very short timescale. Both ecological and hydrological investigations have been denied the opportunity for observations at the scientifically most appropriate times or over the seasons. On-site monitoring is proposed for the detailed design stage, but this will also be constrained by a tight schedule, with construction work due to begin next summer. The timescale of the feasibility study and the design stage taken together, one year from June to June, is insufficient to allow the full description and characterisation of the existing system at Redwick. Given the interdigitation of the existing drainage system, which

in places has been held to justify SSSI notification, with the proposed created wetland systems, disturbance of the reen habitat by the new works is almost inevitable, and uncertainties relating to water quality call into question the long-term co-existence of present communities in the reens with the newly-established wetlands.

2.2. CHAPTER 3 - ENVIRONMENTAL

Page 3.2:- The consultants have quite rightly pruned this list of desired habitats on practical grounds. The introduction of significant saline elements would have been virtually impossible to reconcile with the responsibilities of the IDB and the NRA, and with the presence on site of an SSSI-quality drainage network.

Page 3.7, Section 3.4.2.4:- It should be noted that the quality of the reen aquatic flora depends upon the maintenance of a pattern of hedge-cutting and dredging.

Page 3.10, Section 3.4.4:- There are many references to the high percentage cover of floating aquatics. This may have some relation to the flow in the reens, which is effectively zero during the late summer. Increased reen flow, brought about by the operation of the proposed managed wetlands, could change the distribution of floating aquatics, but in turn this might offer more opportunity for algal growth in phosphate-rich reens. Neither the environmental nor the hydrological study has paid enough attention to the quantity and quality of flows in the reen system.

Page 3.17, paragraph 4:- In view of the total lack of data collected on flow, and the scarcity of data on water quality, in the reens, it is puzzling to note that the authors are of the opinion that "great care will need to be taken to ensure that water quality and flows are maintained", and later (on Page 3.29) that "one of the most important aspects of open water management is the monitoring of water quality"!

2.3. CHAPTER 4 - GEOLOGY

Page 4.4:- Permeability of the sand and gravel is moderate (between 0.26 and 3.5 md^{-1}), with the exception of BH1, which seems to have penetrated a thin (2 m) layer of quite permeable gravels.

Page 4.5, Section 4.4(1):- The estimated yield of a well (assuming permeability of 0.86 md^{-1}) is of the order of 63000 to 95000 m^3a^{-1}, which is equivalent to 35 to 53 mm a^{-1} over the 180 ha of wetland. It is almost certain that this would be insufficient to provide the necessary water supply, and the consultant's solution of a row of wells would be required. The prospect of saline intrusion in response to pumping is very real, and groundwater abstraction from the shallow aquifer should be reserved for the brackish lagoons, if it is required at all.

Page 4.5, Section 4.4 (2):- The option of abstracting deep groundwater has not been explored, and is likely to be expensive. Water quality considerations (e.g. iron and manganese content and discrepancies in major ion composition between surface and ground waters) would also have to be taken into account.

Page 4.6, paragraph 6:- Note the uncertainty with regard to the permeability of clays from the site.

Page 4.6, last paragraph:- Unfortunately IH did not receive a copy of Appendix 4, so it is difficult to comment on this apparent anomaly. If there is a downward gradient, there could be appreciable vertical seepage, which is not taken into account in the hydrology chapter.

2.4. CHAPTER 6 - ENVIRONMENTAL DESIGN

Page 6.2, Section 6.1.6:- The "balanced or positive" water budget is misleading, as the difference between the two major elements, rainfall and actual evaporation, carries considerable uncertainty, and smaller elements, e.g. seepage, are not considered.

Page 6.7, Section 6.2.19:- The plan of the Water Movement System (A/31) shows the incorporation of the existing reen system into the water management of the created wetland, both as a supply and recipient, and connects the reservoir with the existing reen system. This implies some inevitable disturbance to the reens, and by allowing diffuse surface runoff to the reens invites a high suspended sediment yield. It is difficult to see how this could be consistent with the requirement to "create minimal disruption to the existing habitats of the SSSI". Separation of the high-level and low-level reen systems, with a one-way passage of water from the reservoir, through the high-level system and via a small number of engineered outfalls to the existing reens, would appear to be a better means of achieving this objective.

Page 6.7, Section 6.2.20:- By no fault of their own, the consultants are not in possession of sufficient accurate data to determine the water budget as precisely as threshold analysis would require. The results of this analysis are therefore suspect in the extreme.

Page 6.8, Section 6.2.21:- There is no indication in the text or Appendix 6.2 that percolation has been taken into account in the calculations.

Page 6.15, Section 6.5:- The Design Model does show a workable wetland reserve, with the required distribution of habitat types in a sensible spatial arrangement. However, it is probable that the costs of maintaining this reserve could be substantially reduced by an appropriate choice of water levels in the various compartments so that weirs and sluices could be used for water level control instead of pumps. In the long term, the adopted scheme is going to have to exist on a

minimal annual budget and limited staffing levels, and with all the competing pressures the "complex and varied management regime" will not survive far beyond the first year of operation. It is important also to grasp the point that the distribution of water from a single source (i.e. the reservoir) will have water quality implications across the site. Each major water body and habitat will bring about changes in water quality which will be passed on to the next downstream. A programme of water quality monitoring and interpretation, and if necessary measures for the control of localised nutrient enrichment (e.g. by incoming bird populations) must be incorporated into the management plan, and the site operators will need access to a scientific understanding of the workings of each habitat so that its function in relation to the whole site can be maintained in the long term.

3. Overall analysis

The content of the Report has been examined: it is now time to look back at CBDC's Brief to the consultants to see how closely it has been followed. In particular it will be instructive to see what has been left out.

First of all it is important to note that the Brief was not regarded as immutable: the Brief contains the words "it is anticipated that the following work will be required but the list is not to be taken as either including all work items to be considered or a specific requirement that all items in the list will actually be required." (Page 2). The precise content of the Brief was to be negotiated as the work went on, and it is quite possible that modifications have been made by agreement between CBDC and Mason Pittendrigh. Nevertheless, the Brief did represent a consensus between CBDC and other interested organisations as to what would be required, and it is useful at this stage to note any deviations from it, which may reflect on the usefulness of the feasibility study.

Page 2, Section 3.1.i.a:- The study was to include determination of flow mechanisms and flow volumes in reens. Appendix 5.2 describes the levels in the main reens, and the directions of flow, but no flow measurement has been undertaken during the study, and as would have been anticipated at the start of the study no information on flows has been available from the bodies responsible for drainage. In view of the clear importance of the reen system for flood prevention, it is surprising that the consultants have been unable to obtain flood predictions for the NRA reens, or data on the flooding regime of the Caldicot Levels. Even the area of the catchments of the Windmill Reen and Elver Pill Reen appears to be uncertain.

Page 2, Section 3.1.i.d:- The term pollution in the context of Redwick may be taken to comprise saline influences, nutrient enhancement from agricultural activity, and spills or tipping from industrial activity. The approach to the assessment of pollution has been sketchy.

i) electrical conductivity alone is not an appropriate method for detecting brackish water on a site with calcareous soils.

ii) the consultants have attempted to measure levels of nutrients in the reens, though nitrate detection levels were obviously too high. It would have been helpful to look at the other forms of nitrogen and phosphorus (ammonia, organic phosphorus), and some attempt should have been made to sample bed sediments.

iii) the proximity of the steelworks suggests that heavy metal pollution, particularly of bed sediments, is a possibility. At the least, this issue should have been raised with the NRA at an early stage.

Page 3, Section 3.1.v:- The question of the impact of the works on existing nature conservation interests does not seem to have been addressed fully. The proposed new works are not to be allowed to actually remove existing reens or hedges with high ecological value, but the degree of connection between new and existing elements is not specified clearly in the Design Model. It is almost inevitable that some drainage would occur from the created wetlands into the existing reens, even if direct hydraulic connection were avoided. The survival of the present diverse habitat in the reens depends on careful management of inputs to the reens. Relevant aspects of water quality, e.g. the quality of water supplied externally, nutrient enhancement from large numbers of birds feeding off-site and roosting on-site, suspension of sediments by bird activity, and the processes leading to the present water quality in the reens, have not been adequately dealt with by this Report.

Page 3, Section 3.1.vii:- The Report does not include an Environmental Assessment - it is assumed that this has been prepared as a separate document.

Page 3, Section 3.1.viii:- The budget includes capital costs for the construction of the wetland scheme, but no indication of running costs. The success of the scheme in the long term will depend on the acceptance of the role of site operator by some appropriately qualified and committed but as yet unspecified body. The costs of running a visitor centre can be calculated by comparison with existing sites, though obviously much will depend on the number of visitors and the facilities to be offered. Of more concern is labour-intensive habitat management, which ranges from hedge-cutting, reed-cutting, cattle management, reen clearance and sluice operation to wardening and scientific monitoring. The Report has been rather upbeat about the desirability of a complex management plan with full flexibility, without giving consideration to the costs involved, and to the likelihood of a newly-established reserve's being able to field the necessary team of experienced workers.

4. Conclusions

The main criticisms of the Report have been dealt with in detail above. It is proposed in this section to examine the main hydrological issues in the light of CCW's three requirements, which are (briefly) the assessment of:

i) the methods used

ii) interpretation of data

iii) validity of conclusions.

The hydrological aims of the Feasibility Study were to establish the present hydrological regime in the SSSI, to assess the feasibility of changing the land use from grazing to a wetland nature reserve and to produce an outline design for water management on site.

In view of the timescale of the study (which was extremely short by hydrological standards) the consultants have been sensible in relying on desk study and consultation for much of their information. However, where the responsible bodies have not been able to come up with useful data on this very local spatial scale, it was up to the consultants to carry out some fieldwork. This criticism applies particularly to the estimation of reen flows, not only during summer but at times of high flows in winter too. Methods could have ranged from the application of the slope-area method for flow, assisted perhaps by anecdotal evidence from the IDB staff operating the stop-logs, to the estimation of flood flows from catchment characteristics. No account has been given of the limiting effects (if any) of tidal levels on the evacuation of floodwaters - this is information which ought to have been available from the NRA.

Because of the lack of flow data, the Feasibility Study has not contributed greatly to the understanding of hydrological influences on the present ecological state of the reen system, and it is difficult to see how the habitat value of the reens can be conserved without more detailed knowledge of the present regime.

The water budget for the proposed wetland reserve is extremely doubtful, though it is difficult to see how it could be improved without a lengthy programme of hydrological measurements. A major flaw in the Report was the presentation of this budget as a suitable basis on which to assess the areas of various habitats that could be supported in the long term. The feasibility of establishing the wetland reserve with no external supply of water has certainly not been proved. There are also some dangerous assumptions inherent in the Report, notably the disregard for the importance of a through flow of water to control water quality by removing some of the dissolved material, and the supposition that water flowing out of the wetland reserve system will be of appropriate quality for discharge to the existing reen system.

Sampling for water quality was carried out over a reasonable spatial network, considering the overall scale of the Feasibility Study, but the analyses covered an insufficient number of determinands. Each sample should have been analysed for:

eight major ions (pH, calcium, sodium, potassium, magnesium, chloride, sulphate, bicarbonate)

nitrate

ammoniacal nitrogen

phosphate

organic phosphorus

a small selection of trace metals.

In addition, more refined analysis (and if necessary sampling and preservation) methods should have been used for the nutrients.

The consultants' main conclusion, that the development at Redwick is feasible given the possibility of the import of water from off-site, depends on the premises that

i) assuming that the external supply is sufficient in quantity, its quality is appropriate for long-term supply to all the wetland habitats in the scheme. This is not supported by detailed evidence, owing to the confidence ruling imposed by the potential supplier.

ii) any imbalances in the system can be corrected by flexible water management, including drawdown and sludge removal. The scheme proposes a system of management more intensive than is operated in any UK wetland reserve of comparable scale.

iii) water flowing out of the wetland reserve can be discharged to the existing reen system without damage to the SSSI-quality habitats there. There is little evidence to support this.

The timescale of the detailed design phase does not allow of a full eco-hydrological study, either of the present range of habitat at Redwick or of the operation of created habitats. While the scheme for the supply and retention of water is no doubt feasible in strict engineering terms, I must conclude that the consultant's final sentence "the Feasibility Study has shown how all these constraints have been developed into a scheme which could create a wetland of outstanding ecological interest" is a statement of faith rather than a proven conclusion.

TERRESTRIAL AND FRESHWATER SCIENCES DIRECTORATE
Natural Environment Research Council
Polaris House
North Star Avenue
Swindon SN2 1EU
Tel: 0793 411500 Fax: 411502
Telex: 444293 ENVRE G

INSTITUTE OF FRESHWATER ECOLOGY

Windermere Laboratory
Far Sawrey, Ambleside
Cumbria LA22 0LP
Tel: 09662 2468 Fax: 6914
Telex: 94070416 WIND G

River Laboratory
East Stoke, Wareham
Dorset BH20 6BB
Tel: 0929 462314 Fax: 462180
Telex: 94070672 WARE G

Edinburgh Laboratory
Bush Estate, Penicuik
Midlothian, EH26 0QB
Tel: 031 445 4343 Fax: 3943
Telex: 72579 BUSITE G

Eastern Rivers Laboratory
Monks Wood Experimental Station
Abbots Ripton, Huntingdon
Cambs PE17 2LS
Tel: 04873 381 Fax: 467
Telex: 32416 MONITE G

Teesdale Laboratory
c/o Northumbrian Water
Lartington Treatment Works
Lartington, Barnard Castle
Co Durham DL12 9DW
Tel: 0833 50600 Fax: 50827

INSTITUTE OF HYDROLOGY

Maclean Building
Crowmarsh Gifford
Wallingford
Oxon OX10 8BB
Tel: 0491 38800 Fax: 32256
Telex: 849365 HYDROL G

Plynlimon Office
Staylittle, Llanbrynmair
Powys SY19 7DB
Tel: 05516 652 Fax: 441

Balquhidder Office
Tulloch Lodge
Balquhidder, Lochearnhead
Perthshire FK19 8PQ
Tel: 08774 257

INSTITUTE OF TERRESTRIAL ECOLOGY (NORTH)

Edinburgh Research Station
Bush Estate, Penicuik
Midlothian EH26 0QB
Tel: 031 445 4343 Fax: 3943
Telex: 72579 BUSITE G

Banchory Research Station
Hill of Brathens, Glassel
Banchory, Kincardineshire, AB31 4BY
Tel: 03302 3434 Fax: 3303

Merlewood Research Station
Grange-over-Sands, Cumbria LA11 6JU
Tel: 05395 32264 Fax: 34705
Telex: 65102 MERITE G

INSTITUTE OF TERRESTRIAL ECOLOGY (SOUTH)

Monks Wood Experimental Station
Abbots Ripton, Huntingdon
Cambs PE17 2LS
Tel: 04873 381 Fax: 467
Telex: 32416 MONITE G

Bangor Research Unit
University College of North Wales
Deinol Road, Bangor LL57 2UW
Tel: 0248 370045 Fax: 355365
Telex: 61224 BANITE G

Furzebrook Research Station
Wareham, Dorset BH20 5AS
Tel: 0929 551518/9 Fax: 551087

INSTITUTE OF VIROLOGY AND ENVIRONMENTAL MICROBIOLOGY

Mansfield Road, Oxford OX1 3SR
Tel: 0865 512361 Fax: 59962

UNIT OF COMPARATIVE PLANT ECOLOGY
Department of Animal and Plant Sciences
University of Sheffield, Sheffield S10 2TN
Tel: 0742 768555 Fax: 760159
Telex: 547216 UGSHEF G

CENTRE FOR POPULATION BIOLOGY
Imperial College, Silwood Park
Ascot, Berks SL5 7PY
Tel: 0344 23911 Fax: 294339

WATER RESOURCE SYSTEMS RESEARCH UNIT
Department of Civil Engineering, Newcastle University
Newcastle-upon-Tyne NE1 7RU
Tel: 091 232 8511 Fax: 091 261 1182
Telex: 53654 UNINEW G

UNIT OF BEHAVIOURAL ECOLOGY
Department of Zoology, University of Oxford
South Parks Road, Oxford OX1 3PS
Tel: 0865 271165 Fax: 310447

Natural Environment Research Council

Terrestrial and Freshwater Sciences