NATIONAL RIVERS AUTHORITY
AWDURDOD AFONYDD CENEDLAETHOL
Welsh Region

LLYN TEGID DUAL PUMPING SCHEME

PRELIMINARY STUDY REPORT

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EXECUTIVE SUMMARY

1 Introduction

1.1 This report was prepared by Binnie Black & Veatch in response to a request from the National Rivers Authority (NRA), Welsh Region to study the feasibility of pumping water from Llyn Tegid to Llyn Celyn and to the river Dee.

2 Background

2.1 The NRA operates the River Dee Regulation Scheme and is a leading member of the River Dee Consultative Committee. Other members of the committee represent the main water abstractors, namely:

North West Water
Dwr Cymru Welsh Water
Wrexham Water Co
Chester Water Co, and
British Waterways Board

2.2 The three major reservoirs of Alwen, Brenig and Celyn, constructed as new storage, are relatively large for their catchment areas with the result that filling is not assured during years of less than average rainfall. Llyn Tegid, however, was developed by raising the outlet of a natural lake and drains a relatively large catchment. In every year since its raising, Llyn Tegid has received ample inflow, using its variable storage capacity to reduce flood peaks and spilling surplus flows into the River Dee.

2.3 Low rainfall during the summer and autumn of 1995 has left the existing reservoirs significantly depleted. It is feared that should another dry year ensue, there will be insufficient water in storage to maintain the required flow in the River Dee. In December 1995 NRA commissioned preliminary study of measures to alleviate possible shortages in 1996 and beyond.

3 Scheme Objectives

3.1 The objective of the required scheme can be summarised as follows:-

Short term emergency measure

- To provide an emergency low lift pumping arrangement, to be in place for September 1996, and capable of pumping up to 6m^3/s from Llyn Tegid to the River Dee. The lake would be drawndown by up to two metres below the reservoir sill level.

Long term operation measure

- To provide a high lift pumping arrangement, to be in place by January 1997, and capable of transferring up to 6m^3/s from Llyn Tegid to Llyn Celyn. The lake would not be drawndown below the reservoir sill level, with only surplus flows being pumped.

3.2 The scheme layout is shown on Drawing no 5099/1/6.1.

4 Low lift pumping arrangement

Pump duties

4.1 This scheme is a short duration emergency project to utilise some of the dead volume of the lake to help meet possible water shortages in the summer of 1996. Pumping would be required for approximately 2-3 months. The likelihood of this situation occurring is approximately 1 in 100 years, so further use of this pumping installation would not again be likely, particularly given the implementation of a scheme to optimise the available storage of Llyn Celyn. A flow rate of 6 m^3/s of water is required to be transferred from Llyn Tegid into the Dee discharge channel; pumping is needed as the lake water level may be drawn down up to 2m below the lake discharge gate sill level of 159m OD.

Floating pontoon

4.2 The most practical and cost effective option is the use of a floating pontoon equipped with suitable pumps and delivery lines to the River Dee channel. The pontoons could be manufactured off site, floated into position and moored by anchoring cables in the required location and be able to operate throughout the required range of lake water levels. The installation can be easily removed when no longer required.

4.3 Pump capacities of about 1000 l/s are common in land drainage and units of this size would have the best prospects for reuse or sale afterwards. We have therefore based our design on the use of 6 x 1000 l/s units.

4.4 We propose the use of two triangular pontoons each containing 3 pumps. The proposed arrangement of the floating pontoons is shown on Drawing 5099/2/A1.

5 Llyn Tegid intake for high lift scheme

5.1 The North East shore of Llyn Tegid is gently shelving. An intake can be located close to the existing shoreline but will require a long approach channel to be dredged. This is preferable to a piped intake extending a long way offshore.

5.2 The proposed intake arrangement is shown on Drawing No 5099/4/C1. A concrete intake structure is sited on the shore of the lake, with a screened inlet to a two metre diameter twin concrete pipeline to the pumping station inlet well. A stoplog arrangement will be included to isolate the station.

6 High lift pumping station

Pump duties

6.1 Maximum flow rates of 6m^3/s (Option A), 4.5m^3/s (Option B) and 3.0m^3/s (Option C) have been considered for transfer of water from Llyn Tegid to Llyn Celyn reservoir. Depending on the amount of water available in Llyn Tegid lower flows may also be pumped to achieve the required volumetric transfer. The pumping station is expected to operate for approximately 4-5 months per year on a fairly continuous basis.

6.2 Pumping head is set mainly by the static head resulting from the difference in elevations of the two lakes which is approximately 138m. Frictional losses are comparatively small for any of the pipeline diameters proposed, producing a total pumping head requirement of about 150m.

6.3 Total power requirements for the pumping system will be about 12MW for Option A, however, one third of this energy can be recovered by the Llyn Celyn hydro power station when the water is discharged to the Afon Tryweryn on it's return to the Dee.

6.4 High capacity pumping plant of the size required is specialised, a survey of equipment available from major UK pump suppliers showed that 3 or 4 duty pumps would be required to meet the specified $6m^3/s$ flow rate. The final choice of pump numbers will depend on the availability of equipment to meet the short project time scale, the required operating flexibility and capital costs.

6.5 An outline station design for Option A is shown on Drawings 5099/5/C2, 5099/6/C3, 5099/7/C4 and 5099/8/C5. Options B and C would require 3 and 2 duty pumps respectively, with a corresponding reduction in the pumping station size.

Site location

6.6 The choice of pumping station site adjacent to the lake is limited due to the layout of Bala and local topography. The site selected is shown on Drawing 5099/4/C1, this offers good access, reasonable intake arrangement and pipeline route, some protection from flooding and is a green field site.

Power supply

6.7 Initial information has been received from MANWEB on the provision of a power supply to the pumping station site. A suitable supply can be made available, by reinforcing existing 132 kV lines into Bala, but it has been indicated that if MANWEB have outages on their system the number of pumps able to run could be restricted. This statement will need to be investigated further but should be able to be overcome in view of the nature of operation of the scheme.

7 Pipeline

7.1 Initial calculations using different combinations of high lift pumps and pipeline diameters for Option A indicate the most economic arrangement to be a single pipe of diameter in the region of 1800mm. This gives an average flow velocity at 6 m^3/s of 2.35m/s. The diameter would be unaltered whether the high lift pumping is single or multi-stage. 1800mm is a manageable size which can be manufactured off-site and transported to the site on conventional vehicles. However it will require specialised techniques for installation.

7.2 For smaller design flows the following pipe diameters apply:

- Option B ($4.5m^3/s$)	1600mm
- Option C ($3m^3/s$)	1300mm

These sizes are easier to obtain and less costly to install as the size reduces.

Pipe type and material

7.3 Materials considered for the high lift pipeline were:

- steel (thick and thin walled)
- ductile iron
- reinforced concrete
- glass reinforced plastic (GRP)

Although it is feasible to manufacture reinforced concrete and GRP pipes with the large diameters and design pressures required, such pipes are not commonly available and would be relatively expensive. Past experience in many parts of the world suggests that large-diameter reinforced concrete and GRP pipes are less reliable than pipes of steel or ductile iron. Reinforced concrete and GRP were therefore dismissed as suitable pipe materials for the high lift pipeline.

Pipeline route

7.4 As suggested in the initial project brief, we examined the route of the abandoned railway track between Bala and Llyn Celyn as a potential route for the pipeline. Whereas the 7.7km route is generally clear of obstructions and provides a smooth gradient, there were found to be significant problems in using this route:

- the track is too narrow to permit effective pipe installation without leasing additional working width from adjacent land
- where it is embanked, the track is narrow and would need to be completely removed to allow installation of an 1800mm diameter pipe
- at certain locations the track traverses land with steep crossfalls making pipe installation difficult
- the track crosses the Afon Tryweryn at two locations - this would not be suitable for the pipeline.

7.5 For the above reasons we have dismissed the option of using the railway track for a significant part of the pipeline route. Although the railway track would be utilised at certain locations, study of the pipeline route was extended to more open land lying to the west of the railway and is shown on Drg No. 5099/9/D1 and 5099/10/D2.

Ground Investigations

7.6 We recommend that a preliminary ground investigation is carried out at the earliest opportunity. Many of the uncertainties in the preliminary engineering designs and associated costs are related to unknown ground conditions. The preliminary investigation can be followed by an investigation for design once the feasibility of construction has been established. This will enable a better value scheme to be engineered with a reduced risk of increases in cost during construction.

8 Llyn Celyn Inlet

8.1 The selected pipeline route approaches Llyn Celyn at an elevation close to that of the dam crest and for the purposes of refilling Llyn Celyn Reservoir a discharge point at or close to the reservoir top water level is preferable.

8.2 The final length of the pipeline route south of Llyn Celyn dam will encounter rock for some 400-500m. The rock is grey fine grained slightly weathered volcanic rock, very strong with vertical joints spaced typically 0.6 to 1m apart. It will require drilling and blasting to assist with excavation.

8.3 The pipeline will discharge into the reservoir some 200m upstream of the dam, well clear of the overflow shaft. With rock close to the surface erosion should not be a problem. Surface protection or a well-defined channel for flow down the reservoir slope is unlikely to be needed.

8.4 The proposed inlet arrangement is shown on Drawing No 5099/11/E1 and 5099/12/E2. Rip rap surface protection is provided to dissipate the energy of the inflowing water using rock excavated from the pipeline trench adjacent to the reservoir.

9 Land Availability and Planning

9.1 Land in the ownership of the NRA or Dwr Cymru Welsh Water has been identified by the NRA. The land at the proposed location of the pumping station is in private ownership and will require early acquisition for the scheme to proceed. The preferred route of the pipeline has been identified subsequent to the NRA initial investigations on land ownership for the disused railway route. However it is still considered that approximately six private owners will be affected. Early indications are that one land agent will be appointed to represent all of the landowners in access and easement negotiations.

9.2 The Scheme will require the approval of the local planning and Snowdonia National Park authorities. A planning meeting is scheduled on 22 January 1996 and the specific planning restrictions or requirements for the proposals will be reported to the Dee Consultative Committee on the 25 January 1996.

10 Cost Estimates and Deliveries

10.1 The capital works costs for the scheme options identified have been estimated and are summarised in Appendix A. The costs exclude land acquisition and compensation payments, NRA staff costs and consultancy fees for studies and design.

11 Implementation

Low lift pumping scheme

11.1 The low lift pumping scheme is a temporary emergency measure and is designed to use pumps and materials that are commonly available. There would be no land acquisition requirements and the temporary works required would be at the road bridge which is owned by the NRA. Assuming that planning constraints would be quickly overcome for such an emergency the proposals are viable in the required timescale. A programme for implementation is shown in Appendix B

11.2 Assuming that the scheme would require to be in operation by the beginning of September 1996, procurement of pumps and electrical control panels would need to be placed on 1 April 1996. Preliminary work not shown on the programme would be required to formulate the detailed design and to establish the form and award of procurement contracts. The timescale for this work would depend on the methods chosen, direct award, competitive tenders etc.

High lift pumping scheme

11.3 The high lift pumping scheme requires permanent installations to be designed and constructed within a very tight timescale. There will be land acquisition requirements and planning application approvals in addition to the probable requirement to conduct a statutory Environmental Statement. Without special powers these requirements would render the scheme impossible within the proposed timescale.

11.4 Assuming that the scheme would require to be operational by January 1997, an immediate start would need to be made on engineering planning and the following activities would need to be started by mid February 1996:-

- Site investigations
- Orders placed for the procurement of pumps and motors
- Civil designs
- Orders to MANWEB to supply 33kV incomer

11.5 A programme of the critical activities is shown in Appendix B.

11.6 It is clear that even given special powers to overcome land, planning and environmental constraints conventional design and award of competitive tenders could not be accommodated within the time available. Negotiated contracts would almost certainly be required for all aspects of the scheme however coordinated. Evenso, the scale of the works proposed would require an extremely challenging programme and completion by January 1997 could not be guaranteed.

LLYN TEGID DUAL PUMPING SCHEME

1 Introduction

1.1 This report was prepared by Binnie Black & Veatch in response to a request from the National Rivers Authority (NRA), Welsh Region to study the feasibility of pumping water from Llyn Tegid to Llyn Celyn and to the river Dee.

1.2 The scope of the study was agreed with the NRA at a meeting on the 14th December 1995.

1.3 Binnie Black & Veatch carried out the preliminary study between 14th December 1995 and 19th January 1996.

2 Background

2.1 The River Dee is of national importance in terms of conservation, fisheries, renewable energy resource and water supply. It rises in the mountains of the Snowdonia National Park and flows east towards the Cheshire Plain before turning northwards to reach the sea near the industrial conurbations of the Mersey Valley.

2.2 During the later half of the 19th Century the rise in demand for industrial and domestic water led to construction of storage reservoirs which provided an increasing degree of regulation to the flow of the River Dee. Today the Dee has become one of the most comprehensively managed river basins in Europe combining the functions of flood control, fisheries preservation, amenity, renewable energy and water supply.

2.3 Of the Dee's total 2088km^2 catchment area, 371km^2 drain directly to the reservoirs of Alwen (26km^2), Llyn Brenig (23km^2), Llyn Celyn (60km^2) and Llyn Tegid (Bala Lake) (262km^2) respectively. Whereas water from Alwen Reservoir passes directly to supply, the three reservoirs of Brenig, Celyn and Llyn Tegid are used conjunctively to regulate the flow of the River Dee to reduce flooding and to assure the availability of water supplies abstracted in its lower reaches.

2.4 The NRA operates the River Dee Regulation Scheme and is a leading member of the River Dee Consultative Committee. Other members of the committee represent the main water abstractors, namely:

North West Water
Dŵr Cymru Welsh Water
Wrexham Water Co
Chester Water Co, and
British Waterways Board

2.5 The three major reservoirs of Alwen, Brenig and Celyn, constructed as new storage, are relatively large for their catchment areas with the result that filling is not assured during years of less than average rainfall. Llyn Tegid, however, was developed by raising the outlet of a natural lake and drains a relatively large catchment. In every year since its raising, Llyn Tegid has received ample inflow, using its variable storage capacity to reduce flood peaks and spilling surplus flows into the River Dee.

2.6 Low rainfall during the summer and autumn of 1995 has left the existing reservoirs significantly depleted. It is feared that should another dry year ensue, there will be insufficient water in storage to maintain the required flow in the River Dee. In December 1995 NRA commissioned preliminary study of measures to alleviate possible shortages in 1996 and beyond:

3 Scope of Study

3.1 The outline brief for the preliminary study as discussed and agreed at the introductory meeting of 14 December 1995 comprised the following:

- prepare preliminary options for the scheme, these would include:-
  - optional flow rates up to 6.0m³/s for both low head and high head pumping,
  - consider stage pumping arrangement for high head,
  - consider the possibility of using the same pump sets for low head and high head duties.
- Llyn Tegid intake arrangements. Preliminary design considerations.
- Pumping station siting, sizing, preliminary arrangement and pump selection.
- Selection of pipeline diameter, route and preliminary design details.
- Preliminary design and Celyn inlet arrangement.
- Preliminary design of River Dee discharge arrangement
- Identify land availability.
- Consider planning constraints.
- Identify supply time for main elements - pumps, valves, switchgear, pipes, availability of electrical power.
- Produce Implementation programme.
- Produce scheme capital and operational costs.

3.2 The emergency pumping measures would be programmed to be in place for September 1996 and the Tegid to Celyn works would be required December 1996 / January 1997.

3.3 Binnie Black & Veatch were requested to present their interim findings on feasibility and costs at a meeting with NRA at Bala on 15 January 1996 for the report to be tabled at the Dee Consultative Committee Meeting on 25 January 1996.

4 Assumptions and Constraints

4.1 In carrying out the preliminary study in a short period of time, we have made a number of assumptions and constraints as follows:-

Safety - we regard safety of the works during construction and subsequent operation of the scheme as paramount in any outline designs.

High lift pumping arrangement -hydropower alternatives - whilst the scope exists to determine the feasibility of the incorporation of a hydropower/pumped storage scheme, detailed consideration is excluded from this study. Such a scheme would require a radically different arrangement for the civil work and M&E plant.

High lift pumping arrangement - standby capacity - no standby pumps or motors will be provided. It is assumed that there will be sufficient down time through the summer months to carry out preventive maintenance.

Power supply - standby capacity - one standby transformer will be installed as part of the permanent works.

Low lift pumping arrangement - since it is envisaged as a rare event, low lift pumping arrangements may be of temporary construction. To allow this facility in the long term, the high lift pumping scheme may be constructed to permit occasional transfer of up to 6 m^3/s into the River Dee.

Low lift pumping arrangement - standby capacity - since low lift pumping is envisaged as a rare event, standby pumps or motors will not be required.

Procurement basis - as an "emergency" scheme the NRA will be empowered to by-pass normal procedures, allowing:

- speedy occupation and/or acquisition of land required for the scheme
- negotiation of consultancy, construction and supply contracts as required

Scheme operation - for the purposes of this study the high lift scheme will be operated solely by NRA or its agents to provide regulation and hence ensure the reliable yield of the River Dee.

Planning issues - the aesthetic requirements of the scheme will be no more stringent than for other development in a National Park. As an "emergency" scheme the NRA will be entitled to receive priority treatment in the review of planning applications.

Disruption to the local community - we assume that all reasonable measures will be taken to minimise disruption to the local community and to tourists visiting the area. This may include restrictions to the contractor's working day and week, restrictions to the timing of contractor's deliveries, the use of thrust boring under busy roads etc.

Power supply - although not an integral part of the scheme as studied, the local electricity utility will be able to provide the required 33kV supply to Bala by 1 January 1997.

Control systems - the high lift pumping station will be designed as an unmanned installation. Normal control will be from NRA central control complex interlinked as necessary with existing reservoir level sensing and river flow-monitoring systems.

4.2 A number of constraints identified during the study have a significant bearing on the nature of the scheme and the implementation programme:

Manufacturing delays - given that certain items of mechanical and electrical plant must be procured within a short period, the optimum equipment may not be available.

Materials availability - certain major items of equipment may be difficult to obtain at short notice within the United Kingdom. For example, we understand that large-diameter steel or ductile iron pipe may need to be procured from abroad.

4.3 Planning and implementation of the proposed scheme within the specified timescale is ambitious and will require a radical approach to certain issues which would otherwise delay and/or limit the scope of such an undertaking. In order to complete the high lift scheme and have it operating by the desired deadline, it will be necessary to address planning and procurement issues in terms of "emergency" works. Nevertheless, certain fundamental requirements cannot be circumvented and considerable effort will be required on the part of NRA and its agents to ensure that these are satisfactorily addressed. Issues seen as falling into this category, but outside the scope of this study, are:

Public perception - local residents may resent the disruption caused by the scheme. Positive action will be required to satisfy residents that all reasonable steps are being taken to guarantee the safety of the construction works and minimise any disruption.

Local interests - as a popular tourist destination throughout the year, Bala and its surrounding area is heavily reliant on the tourist industry. Considerable effort must be made to minimise any reduction in the volume of tourist traffic and the ability of the local population to cater for their needs. Where this can not be guaranteed, consideration should be given to appropriate compensation. Whilst progress of the scheme will be of the upmost importance it may be necessary to impose restrictions on the contractor's working day and week, restrictions to the timing of contractor's deliveries.

Environment - although outline designs will seek to minimise obvious detrimental impacts to the environment during construction and subsequent operation of the scheme, systematic analysis and compliance with existing procedures are not included in this study.

5 Investigations and surveys

5.1 The following investigations have been carried out during this preliminary study:-

- Consultations with NRA staff regarding the predicted operational regime of the proposed scheme
- Site inspections for alternative sites for the Llyn Tegid intake, pumping station, pipeline and Llyn Celyn discharge
- An initial geotechnical assessment of the Llyn Tegid intake, pumping station, pipeline and Llyn Celyn discharge
- Coordination With NRA legal Staff regarding the land requirements and availability
- Inspection of record drawings of the Bala Lake Scheme and Llyn Celyn Reservoir.

- Enquiries to MANWEB regarding the availability and cost of the required electricity supply

- Enquiries to pipe manufacturers regarding the availability and costs of alternative diameter and material

- Enquiries to pump manufacturers regarding pump manufacturing times and costs

6 Scheme Objectives

6.1 The objective of the required scheme can be summarised as follows:-

Short term emergency measure

- To provide an emergency low lift pumping arrangement, to be in place for September 1996, and capable of pumping up to 6m³/s from Llyn Tegid to the River Dee. The lake would be drawndown by up to two metres below the reservoir sill level.

Long term operation measure

- To provide a high lift pumping arrangement, to be in place by January 1997, and capable of transferring up to 6m³/s from Llyn Tegid to Llyn Celyn. The lake would not be drawndown below the reservoir sill level, with only surplus flows being pumped.

6.2 The scheme layout is shown on Drawing no 5099/1/6.1.

7 Low lift pumping arrangement

Pump duties

7.1 This scheme is a short duration emergency project to utilise some of the dead volume of the lake to help meet possible water shortages in the summer of 1996. Pumping would be required for approximately 2-3 months. The likelihood of this situation occurring is approximately 1 in 100 years, so further use of this pumping installation would not again be likely, particularly given the implementation of a scheme to optimise the available storage of Llyn Celyn. A flow rate of 6 m³/s of water is required to be transferred from Llyn Tegid into the Dee discharge channel; pumping is needed as the lake water level may be drawn down up to 2m below the lake discharge gate sill level of 159m OD.

7.2 The pumping head is set by the emergency minimum lake level of 157m OD and the Dee channel operating water level at the B4391 road bridge crossing for a flow of 6m³/s which is estimated at 161.3m OD giving a static head of 4.3m. Friction losses in pipework and fittings will be approximately 2.7m generating a total pumping head of 7m. Power consumed by the pumps will be about 450-500 kW depending on the pumps chosen.

Design options

7.3 This scheme is very much a short duration emergency project, it is therefore desirable to minimise non-recoverable capital costs and simplify construction as much as possible to enable the time scale to be achieved. Options considered for this scheme included:-

- Pumps on the bank of the lake
- Fixed platform
- Use of the permanent high lift scheme
- Floating pontoon

Pumps on the bank of the lake

7.4 The lake shore in the area concerned is shallow sloping which means that pump intakes would have to be located approximately 400m out into the lake to enable the required drawdown to be achieved. Pumps on the bank are not practical due to the required length of the suction lines, given the size of units needed. This makes this option unattractive.

Fixed platform

7.5 A fixed platform would be relatively costly and could be difficult to construct and operate especially given the range of lake water levels which may be encountered.

Use of permanent high lift scheme

7.6 Incorporation of the low lift scheme with the high lift pumping station would be difficult. The pumps required for the high lift duty are incompatible with the low lift duties. It would also be necessary to deepen and lengthen the high lift pumping station intake to achieve the lake drawdown needed. The deepened intake and wet well civil works would be difficult to construct in the time available for implementation of the low lift scheme. A combined intake to meet both the low and high lift requirements would inhibit the uninterrupted completion of the high lift station and increase the difficulty of meeting both of the deadlines for completion. A combined intake is not therefore recommended.

Floating pontoon

7.7 The most practical and cost effective option is the use of a floating pontoon equipped with suitable pumps and delivery lines to the River Dee channel. The pontoons could be manufactured off site, floated into position and moored by anchoring cables in the required location and be able to operate throughout the required range of lake water levels. The installation can be easily removed when no longer required.

7.8 The alternatives of hiring or procuring pumps was investigated, both options are possible within the time scale. Hire pumps are available up to flow rates of about 300-400 l/s. Approximately 20 pumps would be needed for a $6m^3/s$ output. Assuming hire for an 18 week period at £450/week a total pump hire cost of £171,000 would be incurred. This compares with procurement of new units which would cost approximately £70,000-100,000 depending on pump selection with a possible resale recovery value. Clearly procurement is more cost effective.

7.9 Procurement of three large pumps each of $2m^3/s$ would represent the least capital outlay, however these would be very large custom made units which are unlikely to be re-usable elsewhere. Capacities of about 1000 l/s are common in land drainage and units of this size would have the best prospects for reuse or sale afterwards. We have therefore based our design on the use of 6 x 1000 l/s units.

7.10 A number of pontoon designs were considered. Grouping the 6 pumps on one structure was difficult due to pipework arrangements and the need to achieve good stability. We therefore propose the use of two triangular pontoons each containing 3 pumps. The proposed arrangement of the floating pontoons is shown on Drawing 5099/2/A1.

7.11 The pontoons will consist of a triangular support framework, a top skin plate and cylindrical floats at corner. Canister type axial flow submersible pumps will be mounted within the skin plate. The structure will be fabricated steel and the floats will be filled with polyurethane foam.

7.12 We propose that six MDPE delivery pipelines will connect the pontoons via tied flexible joints to the discharge arrangement in the Dee channel, which will be formed by stoplogs fitted across the road bridge piers, as shown on Drawing 5099/3/A2.

7.13 Power will be provided to each pontoon via switchgear located in a small temporary building on the lake shore using submersible cables attached to the pipelines. Power will be taken from the local 11kV overhead line network.

7.14 The scheme proposed maximises the possible reuse of equipment when pumping operations finish. Pipework, pumps and electrical equipment should be usable elsewhere. Which leaves only the pontoons and stoplogs, which would have a scrap value.

Environmental impact

7.15 The low lift pumping system will have minimal environmental effect. The pontoons are mostly below water level and will have little visual impact. The main effect will be any environmental implications of drawdown of the lake.

7.16 A general inspection of the slopes around Llyn Tegid showed no obvious signs of significant slope instability. Drawing down the lake is therefore unlikely to cause slope movements and the rate of draw down is likely to be slow enough to allow some equalisation of pore-pressures.

7.17 Lowering the lake waters in Llyn Tegid will expose areas of lake shore. At the upstream and downstream ends of the lake these may be extensive areas which may present an unattractive appearance in the summer months. Lowering lake levels may increase effective stresses particularly in alluvial soils which could cause ground settlement. The effect of this on structures built close to the lake should be considered.

8 Llyn Tegid intake for high lift scheme

8.1 The North East shore of Llyn Tegid is gently shelving. An intake can be located close to the existing shoreline but will require a long approach channel to be dredged. This is preferable to a piped intake extending a long way offshore.

8.2 The proposed intake arrangement is shown on Drawing No 5099/4/C1. A concrete intake structure is sited on the shore of the lake, with a screened inlet to a two metre diameter twin concrete pipeline to the pumping station inlet well. A stoplog arrangement will be included to isolate the station.

8.3 A road crossing of the B4391 will be required. This may be achieved either by pipe jacking or standard construction techniques and temporary road diversion. It is likely to have to contend with poor ground conditions and high ground water levels.

8.4 These works would include repair of the flood embankment supporting the B4391. The rip rap protection is poor and the top part of the embankment has been eroded on the lake side to leave a vertical face 1m high exposing slaty gravel fill.

9 High lift pumping station

Pump duties

9.1 Maximum flow rates of $6m^3/s$ (Option A), $4.5m^3/s$ (Option B) and $3.0m^3/s$ (Option C) have been considered for transfer of water from Llyn Tegid to Llyn Celyn reservoir. Depending on the amount of water available in Llyn Tegid lower flows may also be pumped to achieve the required volumetric transfer. The pumping station is expected to operate for

approximately 4-5 months per year on a fairly continuous basis.

9.2 Pumping head is set mainly by the static head resulting from the difference in elevations of the two lakes which is approximately 138m. Frictional losses are comparatively small for any of the pipeline diameters proposed, producing a total pumping head requirement of about 150m.

9.3 Total power requirements for the pumping system will be about 12MW for Option A, however, one third of this energy can be recovered by the Llyn Celyn hydro power station when the water is discharged to the Afon Tryweryn on it's return to the Dee.

Design options

9.4 The number of pumping stations to be used along the transfer scheme was considered. Essentially this is an optimisation of the pipeline and pumping station costs. For this scheme it is clear that the costs of the pumping stations will be high in proportion to the pipeline and that a single pumping station at Llyn Tegid should be utilised.

9.5 Three potential arrangements of pumps were considered: vertical suspended wet well pumps, horizontal split casing pumps and vertically mounted split casing pumps. Assessment of the costs of plant and the civil works for the three designs showed that split casing pumps were likely to be cheaper. Due to the possibilities of flooding and the importance of the station operating when needed, vertically mounted split casing pumps have been selected. This allows motors to be sited above flood levels.

9.6 High capacity pumping plant of the size required is specialised, a survey of equipment available from major UK pump suppliers showed that 3 or 4 duty pumps would be required to meet the specified $6m^3/s$ flow rate. The final choice of pump numbers will depend on the availability of equipment to meet the short project time scale, the required operating flexibility and capital costs.

9.7 Following initial discussions with NRA on the pattern of operations of this scheme, it was concluded that infrequent short duration loss of pumping capacity for maintenance is not likely to be critical. Available pumps could be operated for longer to make up lost transfer capacity and the likelihood of a major plant failure is very low. It was therefore considered that standby pumps will not be needed. For the purposes of this report we have therefore assumed that 4 duty pumps will be installed.

9.8 An outline station design for Option A is shown on Drawings 5099/5/C2, 5099/6/C3, 5099/7/C4 and 5099/8/C5. Options B and C would require 3 and 2 duty pumps respectively, with a corresponding reduction in the pumping station size.

Site location

9.9 The choice of pumping station site adjacent to the lake is limited due to the layout of Bala and local topography. The site selected is shown on Drawing 5099/4/C1, this offers good access, reasonable intake arrangement and pipeline route, some protection from flooding and is a green field site.

9.10 We recommend that the pumping station is located on a level open area inland of the road to ensure flood protection and a reduced visual impact from the lake.

9.11 An assessment of the geology of the area indicates that the pumping station will be on alluvium where high groundwater levels can be expected. Excavations during construction will require control of groundwater, which will probably need deep wells with submersible pumps. Sheet piling may be needed to support excavations and may be incorporated into the permanent structure.

Pumping station layout

9.12 The twin two metre diameter intake pipes will terminate at the pumping station inlet which is provided with coarse screens. Isolation of individual intakes is possible utilising stoplogs upstream and downstream. Water will pass from the inlet chamber into a distribution channel then over a weir into the wet well compartments. Conventional bellmouth intakes are provided for each pump. The bottom water level in the sump is shown as 159m OD, the lowest lake draw down specified. It should be noted that if the high lift scheme were to be used for emergency drawdown of the lake a further deepening of the sump and intake by 2m would be necessary.

9.13 The pump suction pipework passes into the dry well where the pumps and delivery main are situated. A conventional arrangement is proposed with suction and delivery isolation valves, non slam type reflux valves and fabricated steel pipework.

9.14 Four 3MW motors are mounted on an upper floor at 164m OD. Hardy Spicer type drive shafts connect motors to pumps. Access to the building is at motor floor level. The dry well and motor floor are enclosed by a building which incorporates an overhead crane. Holes are provided in the motor floor to permit access to valves and pipework. Pumps are installed via openings under the motors.

9.15 An electrical annex is incorporated at the rear of the building, this is segregated into 11kV and low voltage (LV) equipment. A basement running below the annex enables cables to be routed into the dry well. Starting transformers are located in bays along the rear wall of the annex.

9.16 The station control panel has been located in the LV room and it has been considered that unmanned automatic operation will be required. Basic personnel facilities would be incorporated in the building for visiting staff.

9.17 External to the pumping station building adjacent to the delivery main would be surge protection equipment which would comprise 3 x 100m^3 horizontal cylindrical vessels, connection pipework and valving. A delivery main flowmeter will be provided in a chamber on site and a pipeline isolation valve chamber will be located at the site boundary.

9.18 At a suitable location an electrical substation will be required, consisting of transformers, switchgear and overhead line connection. This will be in a secure segregated compound. The compound will be at a minimum of 164m OD to protect against flooding.

9.19 A short site access road is provided.

Power supply

9.20 Initial information has been received from MANWEB on the provision of a power supply to the pumping station site. A suitable supply can be made available, by reinforcing existing 132 KV lines into Bala, but it has been indicated that if MANWEB have outages on their system the number of pumps able to run could be restricted. This statement will need to be investigated further but should be able to be overcome in view of the nature of operation of the scheme.

9.21 To provide adequate security of power supply we recommend a single 33kV line is provided with duty and standby 15MVA 33/11kV station transformers. A standby unit will be needed because of the long down time for repair and the resulting total loss of station output.

9.22 MANWEB have indicated that direct on line (DOL) starting will not be acceptable for the proposed motors, so we have therefore allowed for autotransformer equipment to provide an assisted start. Further review of the motor starters will be needed during the design stage.

Environmental impact

9.23 The pumping station will mainly have a visual impact on the environment. The pumping station superstructure will therefore be designed to match local building styles, utilising local materials. Screening of the electricity substation could be needed. The location of the site adjacent to a light industrial area should however assist with planning approvals.

9.24 Pumping noise will be minimised by using sound proofing systems and will be localised within the building. The site is sufficiently remote from local housing and noise should not present a problem.

9.25 There will be temporary environmental implications during construction of the scheme.

10 Pipeline

10.1 Choices to be made in the size and type of pipe and its arrangement are as follows:

- pipe diameter
- pipe type and material
- single or multi-stage
- pipeline route
- construction methods

Option A requires conveyance of up to $6m^3/s$ of water from Llyn Tegid to Llyn Celyn.

10.2 For options B and C smaller pipe diameters may be used. This may in turn have a significant bearing on pipe type and material. The following paragraphs discuss the requirements for option A. Where appropriate, possible changes for smaller flows as in options B ($4.5m^3/s$) and C ($3m^3/s$) are also included.

Pipe diameter

10.3 Initial calculations using different combinations of high lift pumps and pipeline diameters for option A indicate the most economic arrangement to be a single pipe of diameter in the region of 1800mm. This gives an average flow velocity at 6 m^3/s of 2.35m/s. The diameter would be unaltered whether the high lift pumping is single or multi-stage. 1800mm is a manageable size which can be manufactured off-site and transported to the site on conventional vehicles. However it will require specialised techniques for installation.

10.4 Substitution of two smaller-diameter pipes has been considered. Since the scheme does not require continuous operation, there is no advantage in dualling the pipe. Whereas installation of smaller pipes would be simpler, the overall cost of supply and installation of twin pipes would be greater.

10.5 For smaller design flows the following pipe diameters apply:

- option B (4.5m³/s)	1600mm
- option C (3m³/s)	1300mm

These sizes are easier to obtain and less costly to install as the size reduces.

Pipe type and material

10.6 The choice of pipe type is between: - rigid pipe, and
- flexible pipe

Whereas flexible pipe (such as thin-walled steel or GRP) can be less costly to manufacture and transport, its installation cost is generally higher than that for rigid pipe (such as thick-walled steel, ductile iron, concrete). The choice between rigid and flexible pipe is included in the following discussions relating to pipe material.

10.7 Materials considered for the high lift pipeline were:

- steel (thick and thin walled)
- ductile iron
- reinforced concrete
- glass reinforced plastic (GRP)

Although it is feasible to manufacture reinforced concrete and GRP pipes with the large diameters and design pressures required, such pipes are not commonly available and would be relatively expensive. Past experience in many parts of the world suggests that large-diameter reinforced concrete and GRP pipes are less reliable than pipes of steel or ductile iron. Reinforced concrete and GRP were therefore dismissed as suitable pipe materials for the high lift pipeline.

10.8 Of the remaining pipe materials, steel and ductile iron, both are commonly used for large-diameter pressure applications and are relatively easy to obtain. Steel pipes would be protected by a factory-applied external wrapping of glass-reinforced bitumen. For internal protection, steel pipes would have either a factory-applied epoxy coating or in-situ concrete lining. Steel pipes are jointed in the trench by welding and the joints subsequently protected externally and internally.

10.9 Ductile iron pipes would be protected by a loose polyethylene sleeve fitted immediately prior to laying. For internal protection, ductile iron pipes normally have a factory-applied cement mortar or concrete lining. Ductile iron pipe installation uses push-fit rubber ring joints which are subsequently wrapped externally with polyethylene sleeving.

10.10 Initial enquiries suggest that for option A (1800mm pipe size) the choice will be between thin-walled and thick-walled steel. Although ductile iron pipe of 1800mm diameter is obtainable, indications are that it would need to be imported from overseas and would be significantly more expensive than steel pipe.

10.11 For the smaller design flows of options B and C, ductile iron pipe of 1300mm diameter and 1600mm diameter is more readily available within the United Kingdom and at prices comparable to steel pipe.

Pipeline route

10.12 As suggested in the initial project brief, we examined the route of the abandoned railway track between Bala and Llyn Celyn as a potential route for the pipeline. Whereas the route is generally clear of obstructions and provides a smooth gradient, there were found to be significant problems in using this route:

- the track is too narrow to permit effective pipe installation without leasing additional working width from adjacent land
- where it is embanked, the track is narrow and would need to be completely removed to allow installation of an 1800mm diameter pipe
- at certain locations the track traverses land with steep crossfalls making pipe installation difficult
- the track crosses the Afon Tryweryn at two locations - this would not be suitable for the pipeline.

10.13 For the above reasons we have dismissed the option of using the railway track for a significant part of the pipeline route. Although the railway track would be utilised at certain locations, study of the pipeline route was extended to more open land lying to the west of the railway and is shown on Drg No. 5099/9/D1 and 5099/10/D2.

Pipeline Route Topography

10.14 The proposed pipeline route commences at Llyn Tegid with a ground level of approximately 160m OD, and traverses ground which rises to approximately 300m OD on the shores of Llyn Celyn reservoir.

10.15 Much of the ground around Bala town is flat and only a few metres above Llyn Tegid lake level. Bala is protected from flooding by artificial flood embankments.

10.16 North of Bala the topography has a hummocky appearance typical of glaciated terrain. In places rock hills break through the more subdued surface relief of the glacial deposits.

10.17 Surface slopes are typically 5-15°. Streams have incised steep-sided valleys which may be 6-10m deep with side-slopes of 26-30°. Drainage is towards the Afon Tryweryn.

10.18 On the south side of Llyn Celyn and the right abutment of the dam there are steep slopes with outcrops of rock and large boulders.

10.19 There appears to be no evidence for large landslides. Small local landslips may occur on the side slopes of the stream valleys.

Geology

10.20 The geology along the pipeline route includes rocks of Ordovician and Silurian age frequently concealed beneath Quaternary deposits of alluvium and glacial till. The thickness of the superficial deposits is not known. Surface rock outcrops occur north of Bala, occasionally in stream sections on the slopes to the west of Afon Tryweryn, and at Llyn Celyn.

Rocks

10.21 The rock types present are slaty mudstones and siltstones with sandstones, and volcanic rocks, principally tuff with andesite.

10.22 The mudstones and siltstones outcrop along the valley from Bala northwards to Llyn Celyn. Surface exposures are rare and restricted to stream sections such as the Nant Aberbleiddyn and Nant Aberduldog, the railway cutting north of Bala College, and some isolated outcrops on hill slopes.

10.23 The outcrop of volcanic rocks is more limited in extent, extending from the sides of Llyn Celyn reservoir for a distance of about 1km downstream of the dam. The most obvious exposure of the volcanic rocks is on the right abutment of the dam around the car park area

Glacial deposits

10.24 Glacial till is present along the sides of the Afon Tryweryn masking much of the underlying rock. The till comprises mostly firm to stiff grey clay with angular gravel, cobbles and boulders. Boulders may be several metres across. The coarse material is derived from the local rocks but includes a large proportion of acid volcanic rocks, particularly the boulders.

10.25 The rockhead surface resulting from glacial erosion is likely to be uneven and may change elevation abruptly.

10.26 The till may contain pockets or lenses of sand and gravel.

Alluvium

10.27 Llyn Tegid occupies a rock basin within a major glacial valley. It is possible that the lake may have formed partly by the damming of the valley with moraine in the vicinity of the outlet at Bala. However, it appears that an alluvial fan deposited by the waters from the Afon Tryweryn may have infilled the east end of the lake basin blocking the outlet from the lake.

10.28 The alluvium is likely to comprise silty sands and silty gravels. It may contain soft silt layers. The thickness of alluvium is not known but could be greater than 20m.

10.29 The alluvium extends from Llyn Tegid up the valley of the Afon Tryweryn for a distance of about 1.5km. It may overlie till deposits or may have been deposited directly on rock.

Made ground

10.30 Made ground is present in the form of flood embankments and in the developed area south of the A494 where the industrial estate and car parks have been constructed. This area was formerly old railway sidings and a station.

10.31 The dismantled railway which follows the valley of the Afon Tryweryn and may become part of the pipeline route includes artificial cuttings and embankments. The embankments are formed of railway ballast gravel. Much of the railway is overgrown.

Groundwater

10.32 Specific information on groundwater is not available. High groundwater levels and saturated ground can be expected in the alluvium around Llyn Tegid. The alluvium may have a high permeability.

10.33 The till is likely to be of low permeability with poor drainage characteristics. However, lenses or pockets of sands or gravels within the till may contain groundwater. The till softens rapidly when in contact with water.

10.34 The rocks appear likely to be of low permeability. Groundwater is unlikely to cause difficulties.

Engineering Considerations

10.35 A pipeline route has been selected to avoid excessive interference with existing facilities and structures and to minimise the requirement for excavation in rock. An initial reconnaissance survey suggests that of the 7.7km of pipeline route about 1.5km will be excavated in alluvium, some 1.2km may require excavation in rock, with the remaining 5.0km mostly in clay till. The rock surface at the base of the till or alluvium may be very irregular. The survey also highlighted some other features of the proposed route as described in the following sections.

10.36 For approximately 1.5km northwards from the pumping station site the pipeline trench will be excavated mainly in alluvium. Temporary dewatering by well points may be needed for dry excavations. Groundwater lowering by dewatering can cause settlement.

10.37 The pipeline route alongside the B4391 road passes very close to several buildings on the Bala Enterprise Park. Excavations will need to avoid removing support from the foundations for these buildings. Passing through the car park south of the A494 road excavations for the pipeline route may encounter made ground and old foundations from the former railway works area.

10.38 The proposed pipeline will need to cross the A494 where the road is on embankment 2.5-3m high. The route is likely to pass between the fire station, and a British Gas installation. The route will cross the only access to the fire station.

10.39 From the pumping station to the A494 road the pipeline route passes under two overhead power supply lines. There is a sewage pumping station nearby and the pipeline may have to cross a sewage pumping main. The route also crosses the main drain from the car park area, and may encounter a gas supply main at the north end of the car park. The access road to the Enterprise Park must also be crossed, and much of the planting screening the Park will have to be removed. The route will traverse the stone circle at the south end of the car park.

10.40 Beneath the road embankment carrying the A494 footings from the former railway bridge may have been left in place.

10.41 North of the A494 the field appears at times to be waterlogged. The pipeline route will cross this field and then follow alongside the line of the dismantled railway. This portion of the route is on the flood plain of the Afon Tryweryn. The pipeline will cross an outfall pipe discharging to the river about 100m north of the A494 bridge. A mound is visible in the field near the railway. The origin of this mound is not known, although it has the appearance of spoil from a former shaft site. An overhead power line follows the railway line.

10.42 A track crosses the old railway at SH 9156 3670 and north of this the ground begins to rise sharply. The pipeline route could follow the railway through a cutting which has been part excavated in rock for a distance of some 250m. The cutting is about 6m wide at the base with side slopes of 50°. The floor of the cutting is waterlogged. Alternatively the pipeline could pass over the hill to the south of the cutting. The road cutting to the west of this area shows only till in the cut slope.

10.43 In either case the next obstacle is a road crossing of the A4212 where the working area is constricted between the railway embankment, the A4212 and its junction with a secondary road, and the valley of the stream Nant Ffrydan and its arched culverted crossings below the road and railway. The stream is incised into till with side slopes about 4m high. Rock may be present just below the stream bed as it outcrops in the river a short distance away. The use of pipe-jacking to carry out the road crossing is likely to encounter variable and difficult ground conditions for this method.

10.44 To the north of the A4212 crossing the pipeline route is on a bench feature corresponding to the glacial deposits which infilled the former glacial valley of the Afon Tryweryn. West of the pipeline route there is a break in slope beyond which the ground rises more steeply and rock outcrops are frequently seen. East of the pipeline route another break in slope marks the edge of the present Afon Tryweryn valley eroded after the deposition of the glacial deposits. Between these two breaks in slope the ground has a gentle slope generally of 5-10° in an easterly direction. There are several mound or hummock features which may be drumlins or may also be locations where the underlying rock level rises to the ground surface.

10.45 Several stream crossings will be required. Most of these are relatively small streams. However, the Nant Aberduldog and the Nant Aberbleiddyn have eroded incised valleys with steep 20-30° slopes. Placing the pipeline below the stream bed is likely to require excavation into rock and deep excavations in the valley sides to accommodate vertical bends in the pipeline. These excavations may be over 10m deep.

10.46 A number of overhead electricity supply lines on poles to local farms will cross the pipeline route. Near Aberbleiddyn farm (SH 9015 3865) an electricity transmission line with towers crosses the pipeline route. Details of underground services are not known. The pipeline route can avoid the local farms although it may have to cross access roads and tracks to these farms.

10.47 Most of the pipeline route outside of Bala town crosses low grade agricultural land. Most of the field boundaries along the pipeline route are fences or hedges with few walls. There are a number of mature trees which would require felling to allow construction of the pipeline.

10.48 Preliminary indications are that very little of the excavated material will be suitable for backfill surround to the pipe, particularly where thin walled steel pipes or glass reinforced plastic (GRP) pipes may be considered. A suitable disposal area for excavated spoil will be needed. Material for pipe bedding and surround will have to be imported.

10.49 Most of the pipeline will be layed in wet ground, alluvium or clay, where resistivity will be low. In clayey ground sulphate-reducing bacteria may also be present. Appropriate measures to reduce corrosion will have to be considered.

10.50 The pipeline needs to have sufficient cover so that it is not affected by freezing of the ground in cold winter weather; 1m of cover is normally adequate for this in British weather.

10.51 There may be times when the pipeline is empty. In areas of high groundwater, particularly around Bala, sufficient cover should be provided to resist flotation of the pipe.

Ground Investigations

10.52 We recommend that a preliminary ground investigation is carried out at the earliest opportunity. Many of the uncertainties in the preliminary engineering designs and associated costs are related to unknown ground conditions. The preliminary investigation can be followed by an investigation for design once the feasibility of construction has been

established. This will enable a better value scheme to be engineered with a reduced risk of increases in cost during construction.

10.53 The preliminary ground investigation should include boreholes in critical locations, for example:

- pumping station site
- A494 road crossing
- A4212 road crossing
- three major stream crossings
- where existing buildings are close to the preferred route

10.54 Subsequent investigations for design may include additional boreholes, trial pits, and rotary core drilling of rock. These will also allow an assessment to be made of the suitability of excavated materials along the pipeline route for re-use in trench backfilling and elsewhere.

10.55 To gain maximum benefit from the ground investigations we recommend that it is carried out under the full-time supervision of a qualified and experienced geotechnical engineer. In addition we recommend that an engineering geomorphological survey of the pipeline route is carried out as part of the preliminary investigation to assist in planning any future investigation work.

Construction Methods

10.56 Construction of the pipeline, whether of 1800mm or 1300mm diameter, will be a major undertaking. Whereas much effort and cost should be directed at minimise this disruption, much will be unavoidable during the construction period. In open land the long term effects of pipeline construction can be reduced to a minimum.

10.57 For the option A pipeline of 1800mm diameter a temporary working strip of land of approximately 20 metres will be required for storage of stripped topsoil, stringing of pipes prior to installation, access track, temporary spoil tip and for the pipe trench itself (including sideslopes where required). For the option B and C pipelines it may be possible to reduce the working width by a small amount.

11 Llyn Celyn Inlet

11.1 The selected pipeline route approaches Llyn Celyn at an elevation close to that of the dam crest and for the purposes of refilling Llyn Celyn Reservoir a discharge point at or close to the reservoir top water level is preferable.

11.2 The final length of the pipeline route south of Llyn Celyn dam will encounter rock for some 400-500m. The rock is grey fine grained slightly weathered volcanic rock, very strong with vertical joints spaced typically 0.6 to 1m apart. It will require drilling and blasting to assist with excavation.

11.3 The pipeline will discharge into the reservoir some 200m upstream of the dam, well clear of the overflow shaft. With rock close to the surface erosion should not be a problem. Surface protection or a well-defined channel for flow down the reservoir slope is unlikely to be needed.

11.4 The proposed inlet arrangement is shown on Drawing No 5099/11/E1 and 5099/12/E2. Rip rap surface protection is provided to dissipate the energy of the inflowing water using rock excavated from the pipeline trench adjacent to the reservoir.

12 Land Availability and Planning

12.1 Land in the ownership of the NRA or Dwr Cymru Welsh Water has been identified by the NRA. The land at the proposed location of the pumping station is in private ownership and will require early acquisition for the scheme to proceed. The preferred route of the pipeline has been identified subsequent to the NRA initial investigations on land ownership for the disused railway route. However it is still considered that approximately six private owners will be affected. Early indications are that one land agent will be appointed to represent all of the landowners in access and casement negotiations.

12.2 The Scheme will require the approval of the local planning and Snowdonia National Park authorities. A planning meeting is scheduled on 22 January 1996 and the specific planning restrictions or requirements for the proposals will be reported to the Dee Consultative Committee on the 25 January 1996.

13 Cost Estimates and Deliveries

13.1 The capital works costs for the scheme options identified have been estimated and are summarised in Appendix A. The costs exclude land acquisition and compensation payments, NRA staff costs and consultancy fees for studies and design.

High Lift Scheme

13.2 The costings of the high lift scheme have been divided into the following items:-

-Site Investigations
-Llyn Tegid Intake
-High Lift Pumping Station Civil Works
-High Lift Pumping Station M & E Costs
-Pipeline Supply Cost
-Pipeline Construction Cost
-Inlet to Llyn Celyn
-Provision of Electrical Supply

Site investigations

13.3 A sum has been included to carry out an early site investigation. The costing includes for, boreholes and pumping tests at the proposed site of the intake and pumping station, boreholes at the locations where the pipeline crosses roads and streams and trial pits for the remainder of the pipeline route. The scope and cost of the investigations remains the same for all options.

Llyn Tegid intake

13.4 Preliminary drawings for the Llyn Tegid intake have been produced and are included within this report. Quantities for all items of construction and materials have been taken off using these drawings.

13.5 Using rates from the CESMM database a total cost for the construction of the outfall has been calculated. Provisional sums added to the cost based on CESMM include: supply and installation of reinforced concrete pipework; safety/debris screens; pipejacking; dredging; sheet piling; and landscaping.

13.6 The cost for the intake off Llyn Tegid is common to all three pipeline diameters.

Pumping station civil works costs

13.7 Again, quantities have been taken off provisional drawings and rates from CESMM used to calculate the cost of the pumping station.

13.8 The provisional sums added to the cost of the pumping station include: pipework and valves; screens; crane beams and hoists; plumber work; access roads, lighting and heating installation; and landscaping.

13.9 The drawings only detail a pumping station required for Option A. Costs for Option B and Option C were obtained for a similar pumping station arrangement, but with the plan size of the building reduced to house two and three duty pumps respectively.

Pumping station M & E costs

13.10 The costs for the major items of plant are based on equipment manufacturers quotes. The costs of the associated plant, such as surge vessels, are based on rates for similar work on other contracts.

Pipe supply

13.11 For the pipe route from the pumping station at Llyn Tegid to Llyn Celyn we have costed for three possible diameters (1800mm, 1600mm and 1300mm nominal bore) of pipeline for both steel and ductile iron pipe material. As discussed in Section 10 use of other pipeline materials has been dismissed.

13.12 Quotations have been received from both steel and ductile iron pipe manufacturers for the supply of the range of pipe sizes identified. The manufacturers were also asked to specify anticipated delivery periods following the date of order.

13.13 The supply of ductile iron pipes over 1600mm nominal bore is not possible from a United Kingdom source. Quotes for the 1800 mm diameter pipe were obtained from Kubota who would import pipes fabricated in Japan. The quotation was 300 per cent greater than that for the equivalent diameter fabricated in steel and the delivery period was thirty six months. Ductile iron has, therefore, been discarded as a pipe material for the 1800mm diameter pipeline. For pipe diameters of 1300mm and 1600mm the delivery period for ductile iron pipework has been quoted as 10 weeks.

13.14 Quotations for steel pipes, both thick and thin wall thicknesses, were obtained with delivery periods ranging from a minimum of 12 weeks for 1300mm diameter, to a maximum of 22 weeks for 1800mm diameter. The material cost saving for the thin wall steel pipes are not sufficient to offset the additional installation costs and the use of thick walled steel pipes is assumed in the cost summaries.

13.15 The quotations show the optimum material for the 1600mm diameter pipeline to be steel and for the 1300mm diameter to be ductile iron.

13.16 Final contract prices for the manufacture and delivery of a similar 1800mm steel pipeline scheme in the UK have been adjusted to November 1995 prices using Baxter indices. The adjusted contract price, is within 13 per cent of the quoted figures from manufacturers.

Pipeline installation

13.17 The installation costs for the 1800mm diameter pipeline are based on the contract price for same pipeline scheme for the installation of the same pipeline used to verify the supply costs. The costs again being adjusted to November 1995 using Baxter indices.

13.18 The installation cost for the 1600mm and 1300mm pipelines have been interpolated by producing a graph of costs against pipeline diameter based on the above cost for the 1800mm pipeline and the rate of change of installation costs with diameter taken from the CESMM database.

13.19 Additional costs, such as pipejacking and rock excavation have been added to each pipeline installation cost, calculated for November 1995, based on rates extracted from the CESMM database.

Outfall to Llyn Celyn

13.20 Preliminary drawings for the outfall to Llyn Celyn have been produced and are included within this report. Quantities for all items of construction and materials have been taken off using these drawings.

13.21 Using rates from CESMM a total cost for the construction of the outfall has been calculated. Provisional sums for pipework, safety/debris screens, access roads/footpaths and landscaping have then been added.

13.22 The drawings for the outfall detail that required for an 1800mm diameter pipeline. For 1300mm and 1600mm outfalls the cost of the 1800mm diameter outfall have been multiplied by 50 and 75 per cent respectively.

Low lift scheme

13.23 The low lift pumping scheme has been costed under the following items:-

-M & E Costs
-Pontoons
-Stopgates
-MDPE Pipeline Supply
-Installation

M & E costs

13.24 M & E costs for this scheme have been obtained from manufacturers quotations for pumps and the estimated cost for the supply of electrical control equipment.

Pontoons & stopgates

13.25 Quantities of materials have been estimated from preliminary designs and the costs derived using the CESMM database.

MDPE pipeline supply and installation

13.26 Supply costs have been obtained from manufacturers for polyethylene pipe. The installation costs have been estimated.

14 Implementation

Low lift pumping scheme

14.1 The low lift pumping scheme is a temporary emergency measure and is designed to use pumps and materials that are commonly available. There would be no land acquisition requirements and the temporary works required would be at the road bridge which is owned by the NRA. Assuming that planning constraints would be quickly overcome for such an

emergency the proposals are viable in the required timescale. A programme for implementation is shown in Appendix B

14.2 Assuming that the scheme would require to be in operation by the beginning of September 1996, procurement of pumps and electrical control panels would need to be placed on 1 April 1996. Preliminary work not shown on the programme would be required to formulate the detailed design and to establish the form and award of procurement contracts. The timescale for this work would depend on the methods chosen, direct award, competitive tenders etc.

High lift pumping scheme

14.3 The high lift pumping scheme requires permanent installations to be designed and constructed within a very tight timescale. There will be land acquisition requirements and planning application approvals in addition to the probable requirement to conduct a statutory Environmental Statement. Without special powers these requirements would render the scheme impossible within the proposed timescale.

14.4 Assuming that the scheme would require to be operational by January 1997, an immeidate start would need to be made on engineering planning and the following activities would need to be started by mid February 1996:-

- Site investigations
- Orders placed for the procurement of pumps and motors
- Civil designs
- Orders to MANWEB to supply 33kV incomer

14.5 A programme of the critical activities is shown in Appendix B.

14.6 It is clear that even given special powers to overcome land, planning and environmental constraints conventional design and award of competitive tenders could not be accommodated within the time available. Negotiated contracts would almost certainly be required for all aspects of the scheme however coordinated. Evenso, the scale of the works proposed would require an extremely challenging programme and completion by January 1997 could not be guaranteed.

APPENDIX A

COSTS

Table 13.1 - Cost Summary for High Lift Pumping Scheme

Option A	1800 mm Diameter Pipeline - 6 m3/s			
	Section			Estimate
	Site investigaion			£40,000.00
	Intake at Bala			£396,000.00
	Pumping Station			£940,000.00
	Pipe Supply	**Steel**		£3,600,000.00
	Pipe Construction			£5,038,000.00
	Outlet to Lake Celyn			£43,000.00
	M & E			£2,500,000.00
	Electrical Supply			£3,000,000.00
			Sub Total	£15,557,000.00
	Preliminaries	15 **%**		£2,333,550.00
	Contingencies	20 **%**		£3,111,400.00
		GRAND TOTAL		**£21,001,950.00**
Option B	1600 mm Diameter Pipeline - 4.5 m3/s			
	Section			Estimate
	Site Investigation			£40,000.00
	Intake at Bala			£394,000.00
	Pumping Station			£846,000.00
	Pipe Supply	**Steel**		£3,017,000.00
	Pipe Construction			£4,393,000.00
	Outlet to Lake Celyn			£32,000.00
	M & E			£1,875,000.00
	Electrical Supply			£3,000,000.00
			Sub Total	£13,597,000.00
	Preliminaries	15 **%**		£2,039,550.00
	Contingencies	20 **%**		£2,719,400.00
		GRAND TOTAL		**£18,355,950.00**
Option C	1300 mm Diameter Pipeline -3 m3/s			
	Section			Estimate
	Site Investigation			£40,000.00
	Intake at Bala			£396,000.00
	Pumping Station			£658,000.00
	Pipe Supply	**Ductile Iron**		£2,000,000.00
	Pipe Construction			£3,149,000.00
	Outlet to Lake Celyn			£22,000.00
	M & E			£1,250,000.00
	Electrical Supply			£3,000,000.00
			Sub Total	£10,515,000.00
	Preliminaries	15 **%**		£1,577,250.00
	Contingencies	20 **%**		£2,103,000.00
		GRAND TOTAL		**£14,195,250.00**

Table 13.2 - Cost Summary for Low Lift Pumping Scheme

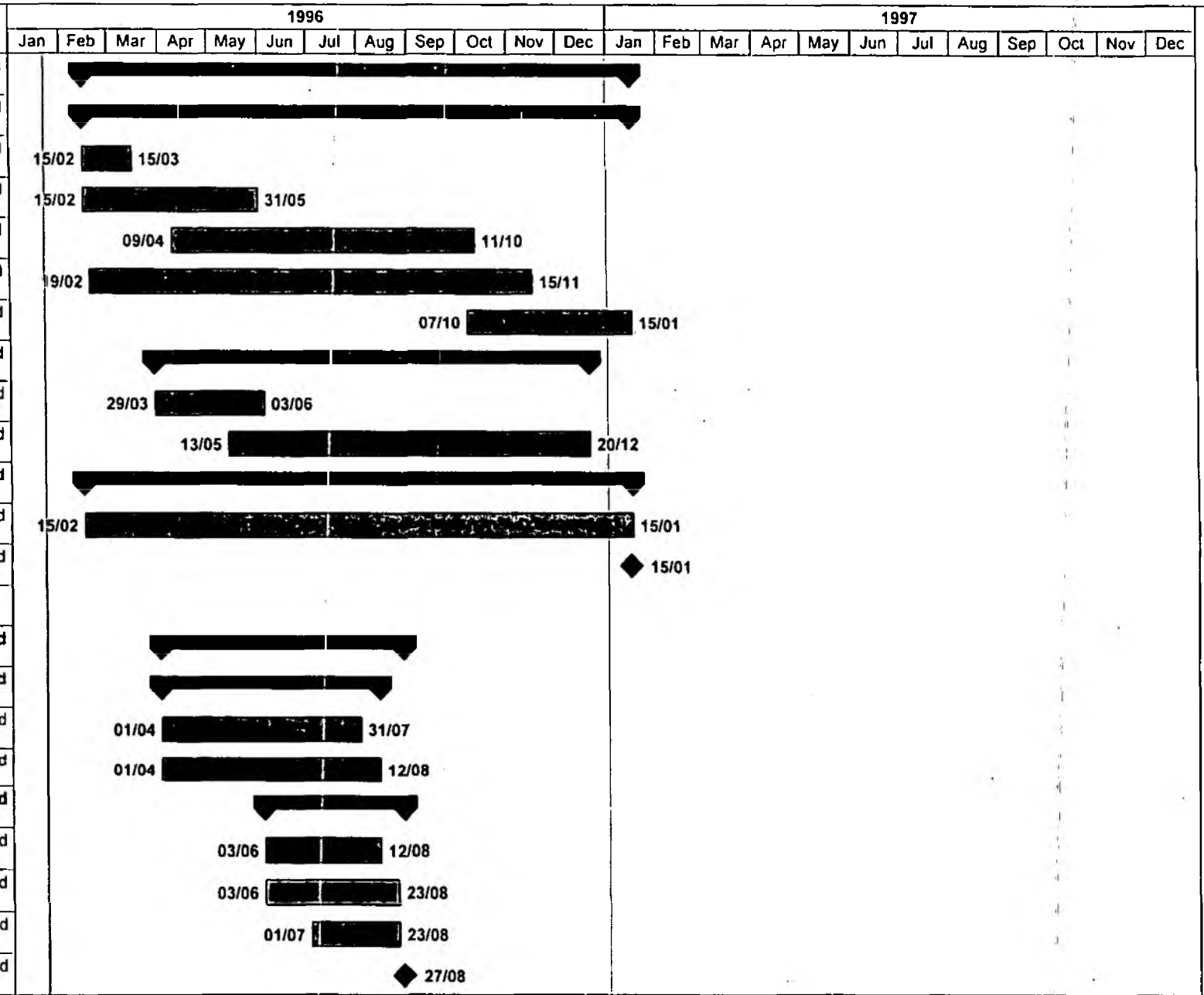
M & E			£120,000.00
Construct pontoons			£22,000.00
Stoplog/gates			£14,000.00
MDPE pipelines	Supply		£168,000.00
	Install		£32,000.00
		Sub Total	£356,000.00
Preliminaries		15 %	£53,400.00
contingencies		20 %	£71,200.00
		GRAND TOTAL	**£480,600.00**

APPENDIX B

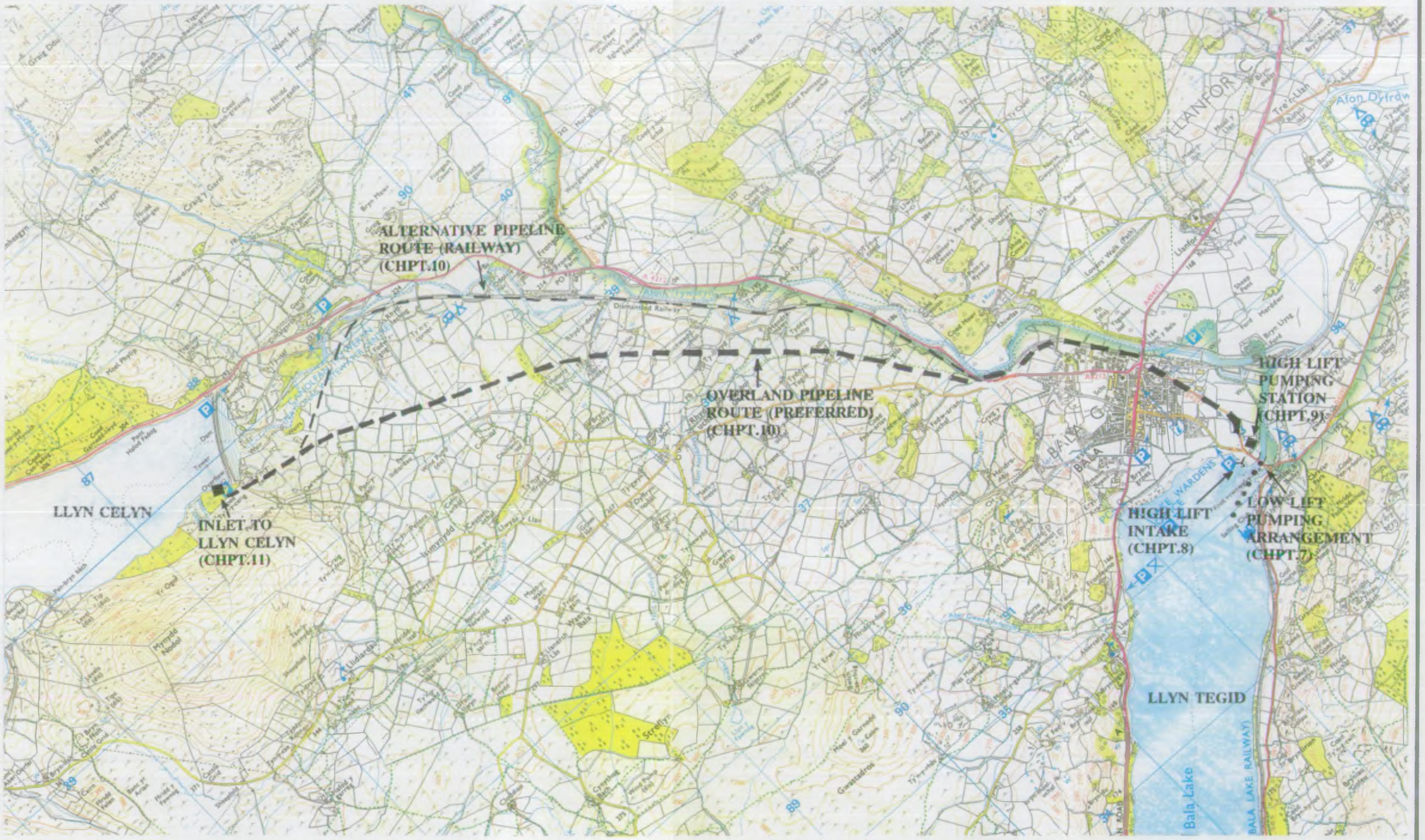
PROGRAMME

Llyn Tegid Dual Pumping Scheme -Critical Activities

ID	Task Name	Duration
1	HIGH HEAD PUMPING	240d
2	Intake and pumping station	240d
3	Site Investigation	22d
4	Design	77d
5	Civil Works Construction	134d
6	M & E Procurement	195d
7	M & E Installation	73d
8	Pipeline	191d
9	Order pipes	47d
10	Install Pipeline	160d
11	Electricity Supply	240d
12	33 KV Installation	240d
13	Operation	1d
14		
15	LOW HEAD PUMPING	107d
16	M & E Works	96d
17	Procure pumps	88d
18	Control panels	96d
19	Civil Works	62d
20	Construct pontoon	51d
21	Pipelines	60d
22	Stop gates	40d
23	Operation	1d



DRAWINGS

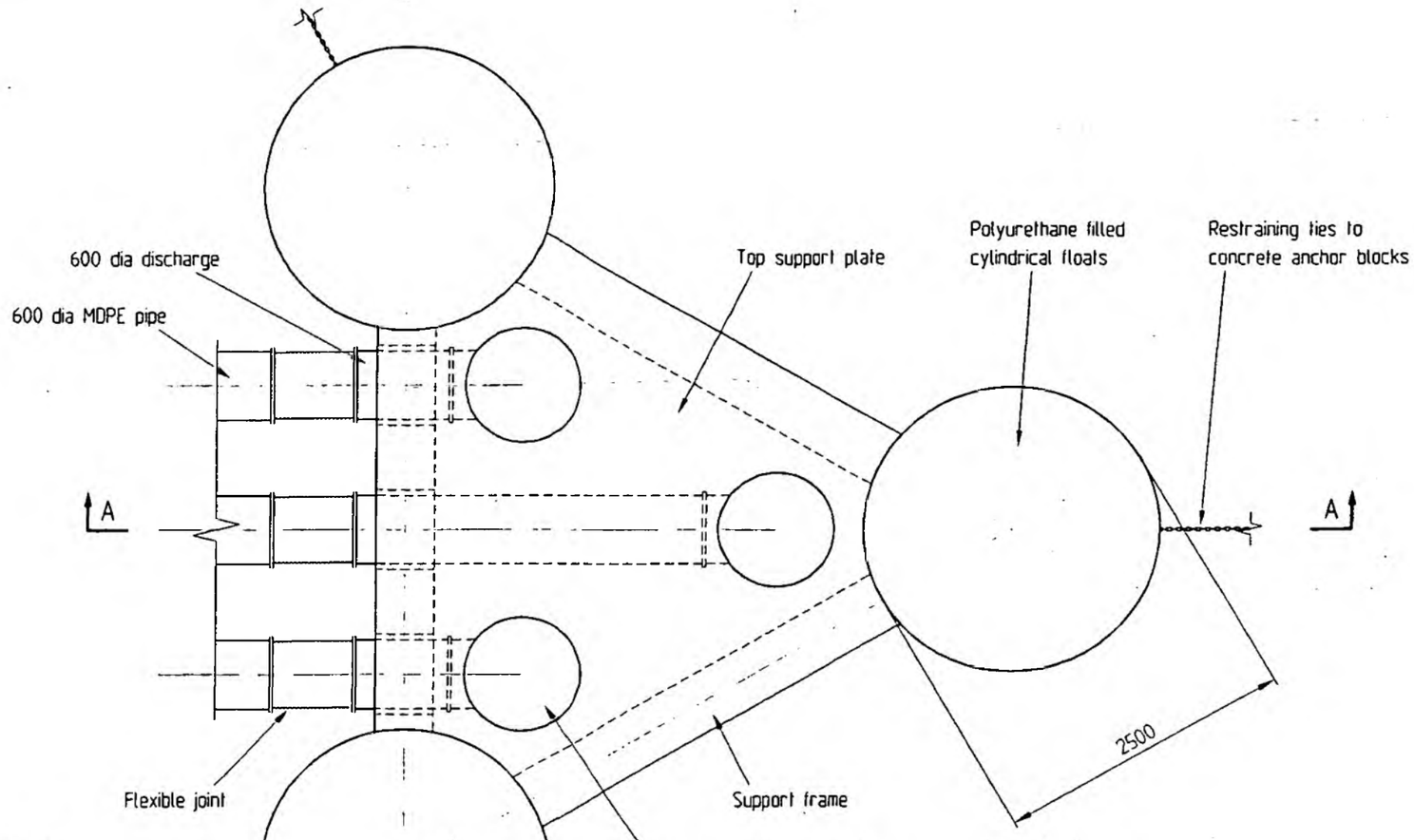


PLAN

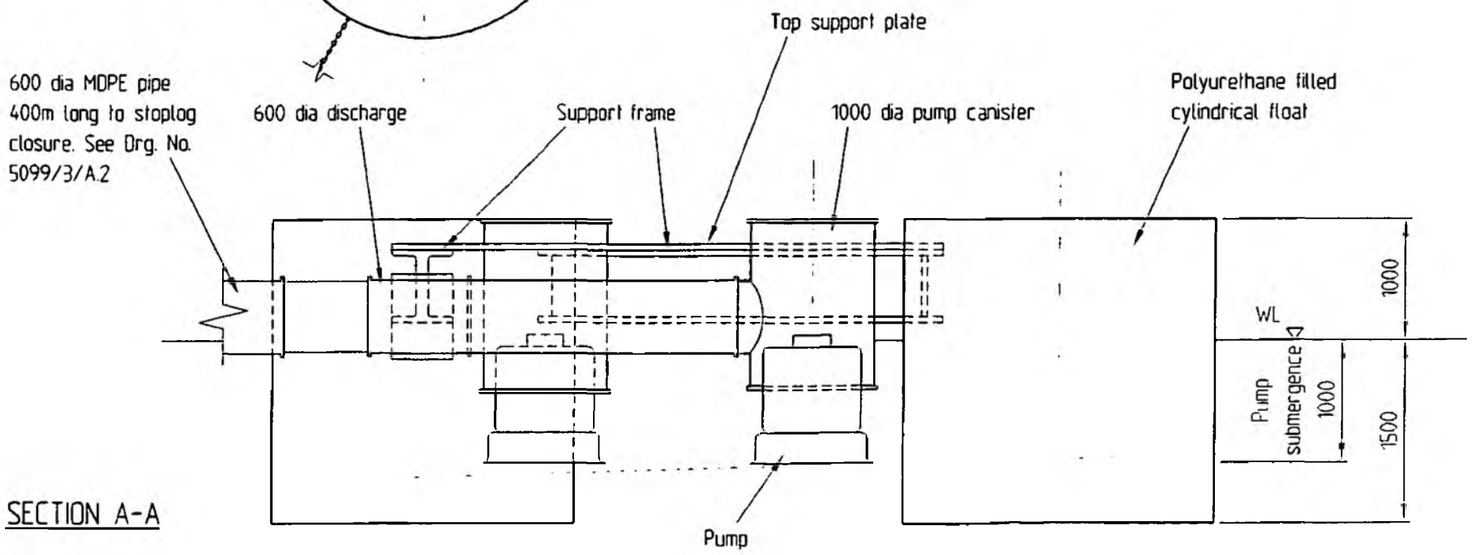
SCALE 1 : 25000

km 1 0 1 2 km

LLYN TEGID DUAL PUMPING SCHEME	
SCHEME LAYOUT	Date: JAN.96
	Drawing no: 5099/1/61



PLAN



SECTION A-A

NOTE

1. Pontoons are located at approximately 400m offshore from B4391 road bridge

SCALE 1 : 50

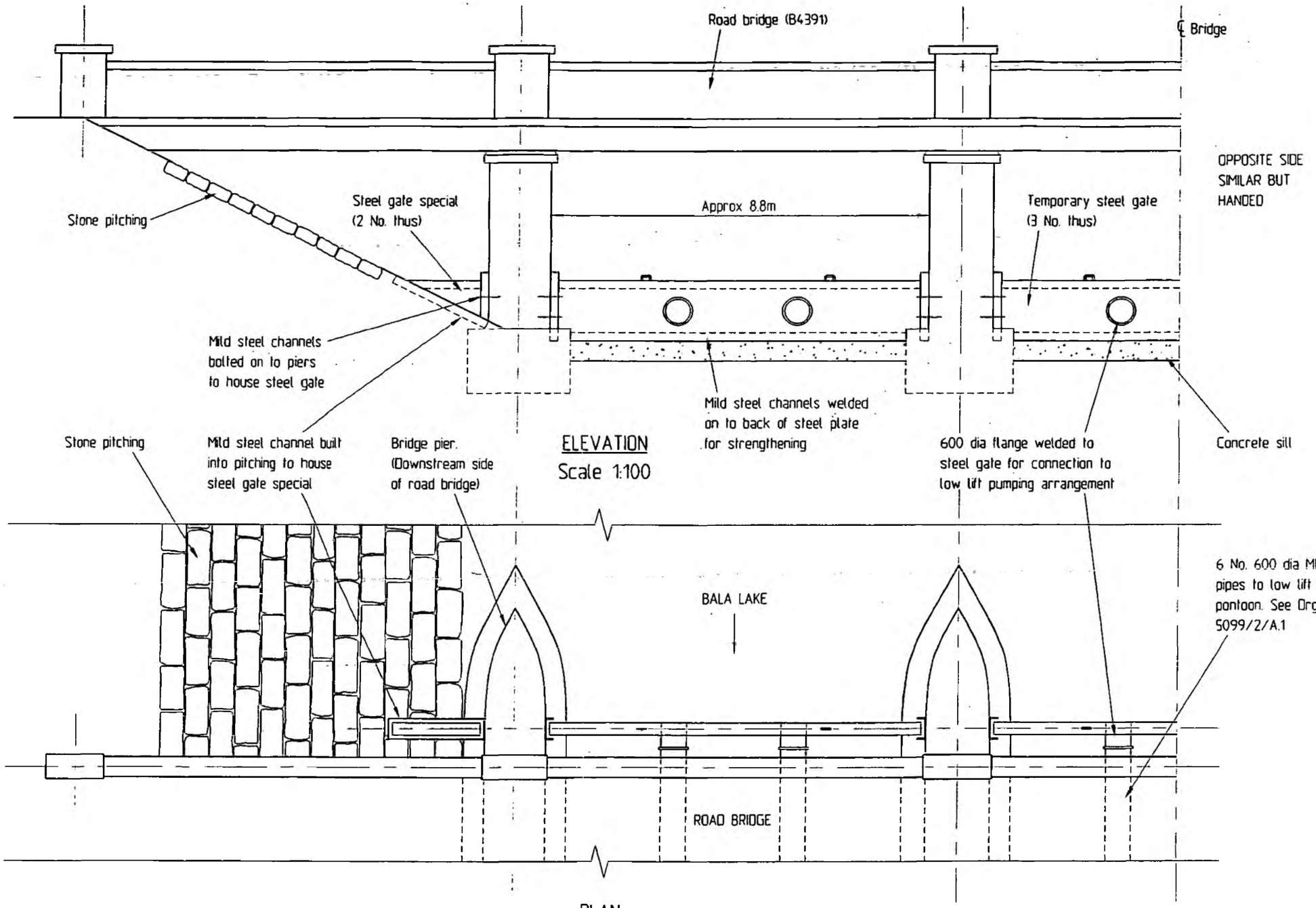
m 1 0 1 2 3 m

LLYN TEGID DUAL PUMPING SCHEME

TEMPORARY LOW LIFT PUMPING ARRANGEMENT

Date: JAN.96

Drawing no. 5099/2/A.1



ELEVATION
Scale 1:100

PLAN
Scale 1:100

SCALE 1 : 100

metre 1 0 5 10 metres

LLYN TEGID DUAL PUMPING SCHEME

STOPLOG DIVERSION DETAIL
PLAN AND ELEVATION

Date: JAN.96

Drawing no. 5099/3/A.2

N

1.8m dia steel pipeline to Llyn Celyn

Flowmeter chamber

High lift pumping station

Surge vessels

Drain

Site boundary

Access road

A

160m

2m dia twin spun concrete intake pipes

Floating pontoons located approximately 400m from bridge

Channel dredged to 155.7m level

A

15m

Reinforced concrete intake structure

Steelwork screen over intake pipes

160m

160m

ROAD BRIDGE (B4391)

For details of channel stoplog closure, see Drg. No. 5099/3/A.2

NOTE

1. For longitudinal section A-A, see Drg. No. 5099/3/A.2

metre 10 0 50 100 metres

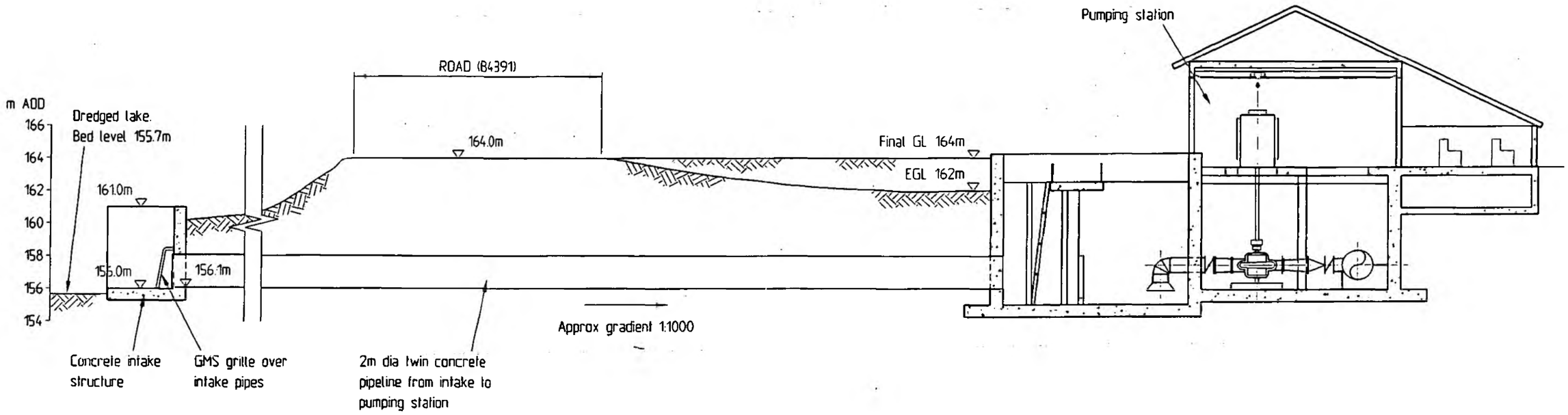
SCALE 1 : 1250

LLYN TEGID DUAL PUMPING SCHEME

HIGH LIFT PUMPING STATION AND INTAKE PLAN

Date: JAN.96

Drawing no. 5099/4/C.1



LONGITUDINAL SECTION A-A THROUGH INTAKE AND PUMPING STATION AT LLYN TEGID

Scale 1:250

SCALE 1 : 250

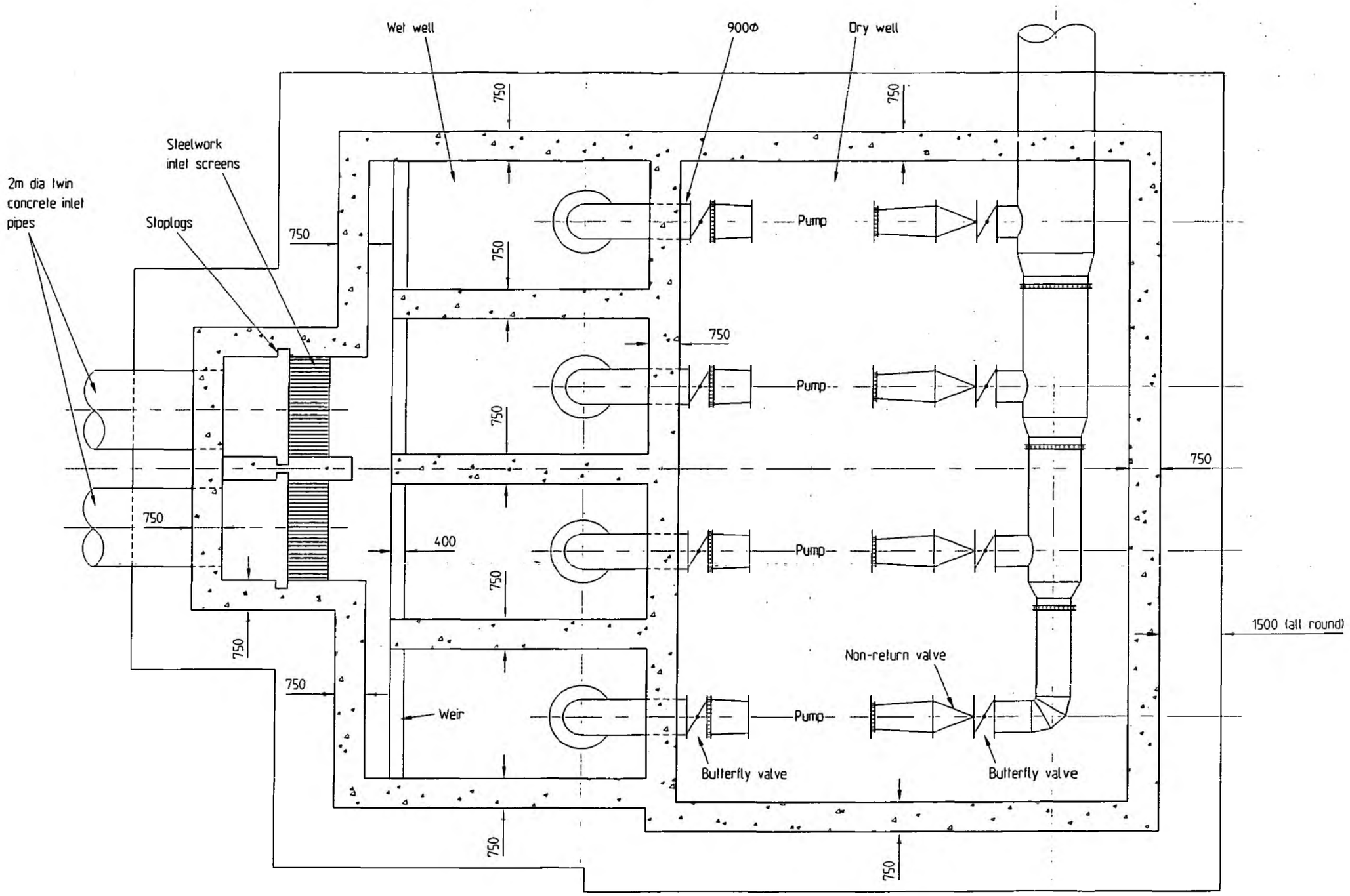
m 5 0 5 10 15 20 25 m

LLYN TEGID DUAL PUMPING SCHEME

HIGH LIFT PUMPING STATION AND INTAKE LONGITUDINAL SECTION

Date: JAN.96

Drawing no. 5099/5/C.2



PLAN ON HIGH LIFT PUMPING STATION AT PUMP LEVEL

Scale 1:100

SCALE 1 : 100

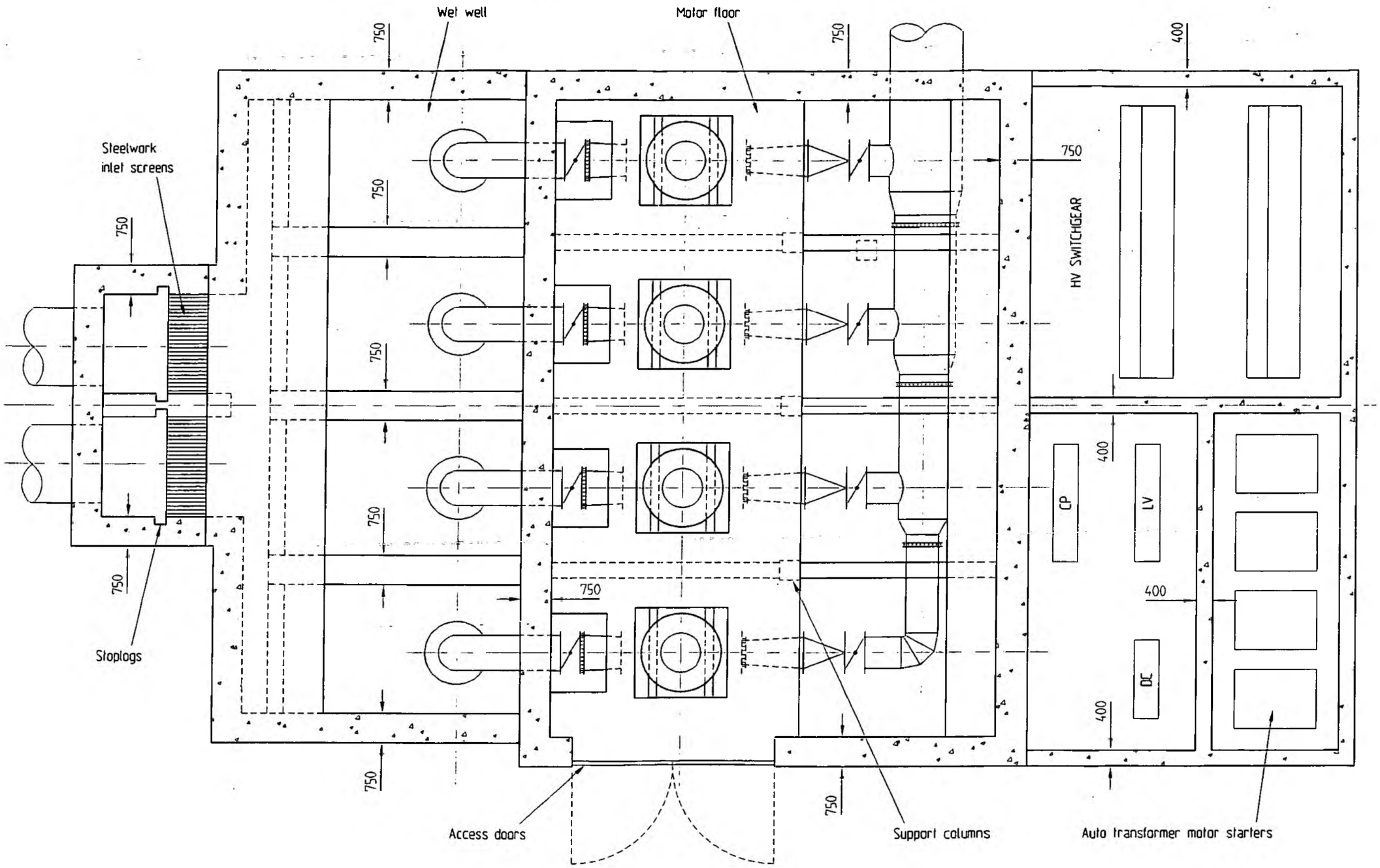
m 1 0 5 10 m

LLYN TEGID DUAL PUMPING SCHEME

HIGH LIFT PUMPING STATION
PLAN 1

Date: JAN.96

Drawing no. 5099/6/C.3



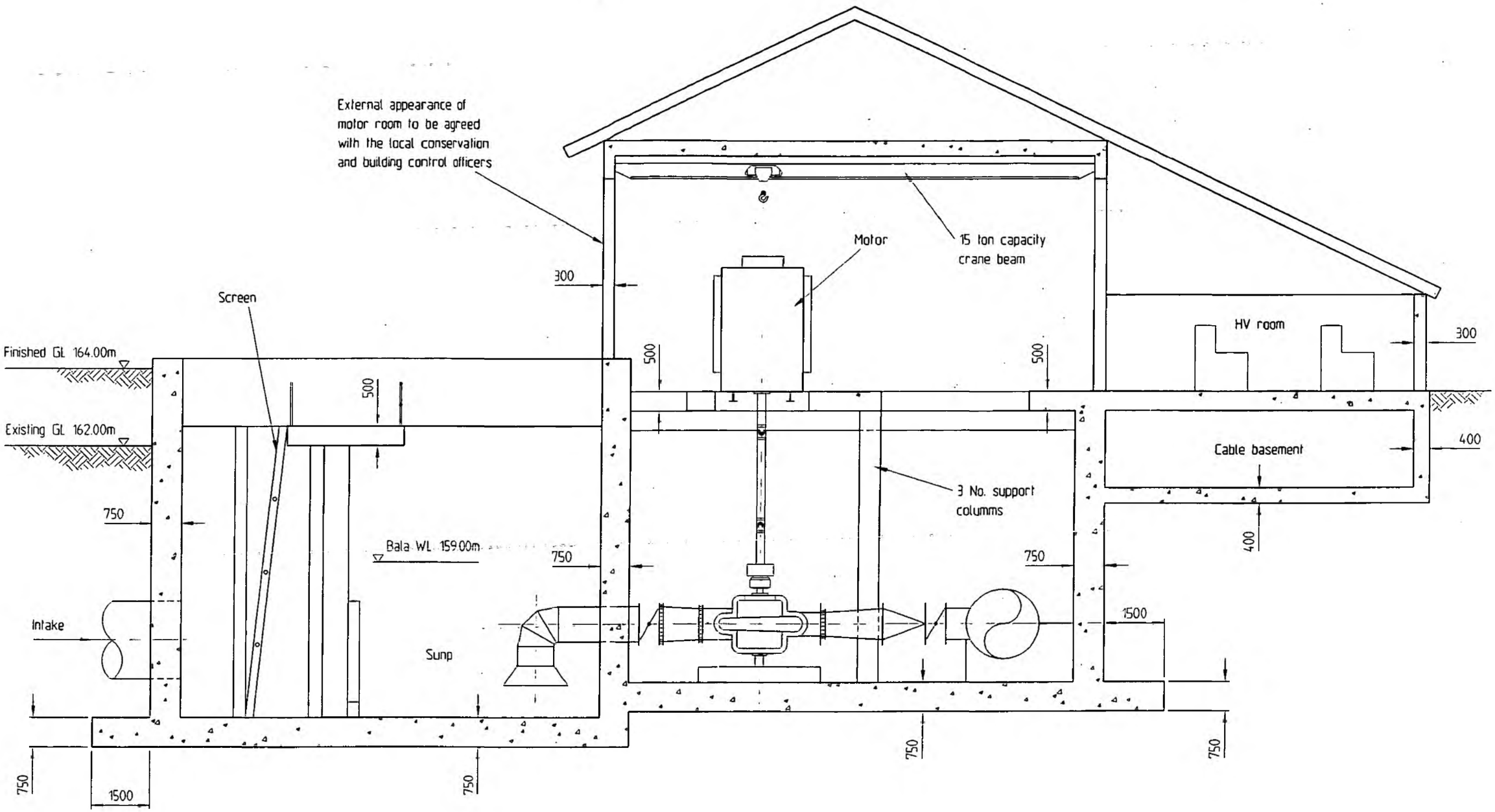
PLAN ON HIGH LIFT PUMPING STATION AT MOTOR FLOOR LEVEL

Scale 1:100

SCALE 1 : 100

m 1 0 5 10 m

LLYN TEGID DUAL PUMPING SCHEME	
HIGH LIFT PUMPING STATION PLAN 2	Date: JAN.96
	Drawing no. 5099/7/C.4



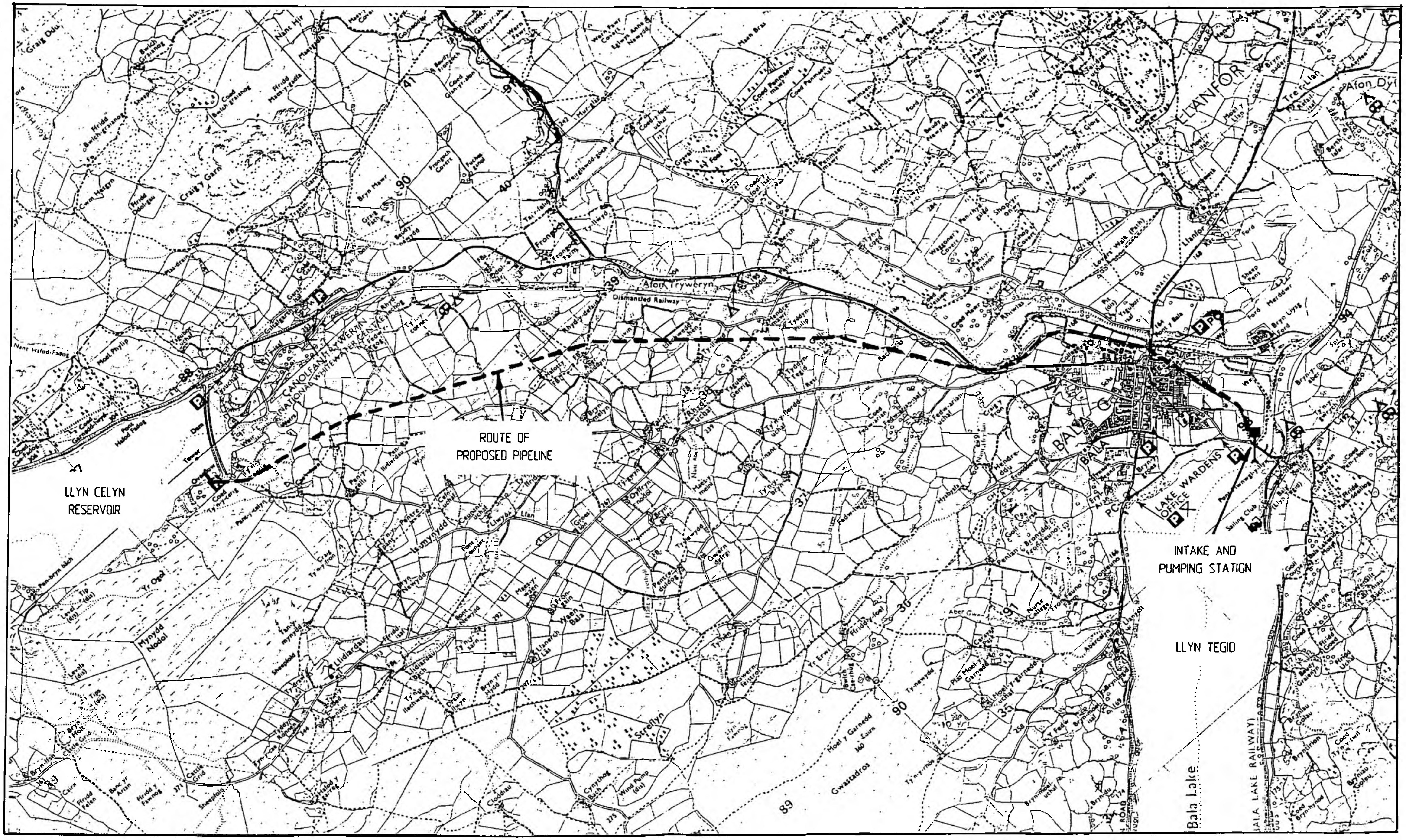
SECTION THROUGH HIGH LIFT PUMPING STATION

Scale 1:100

SCALE 1 : 100

metre 1 0 5 10 metres

LLYN TEGID DUAL PUMPING SCHEME	
HIGH LIFT PUMPING STATION SECTION	Date: JAN.96
	Drawing no. 5099/8/C.5

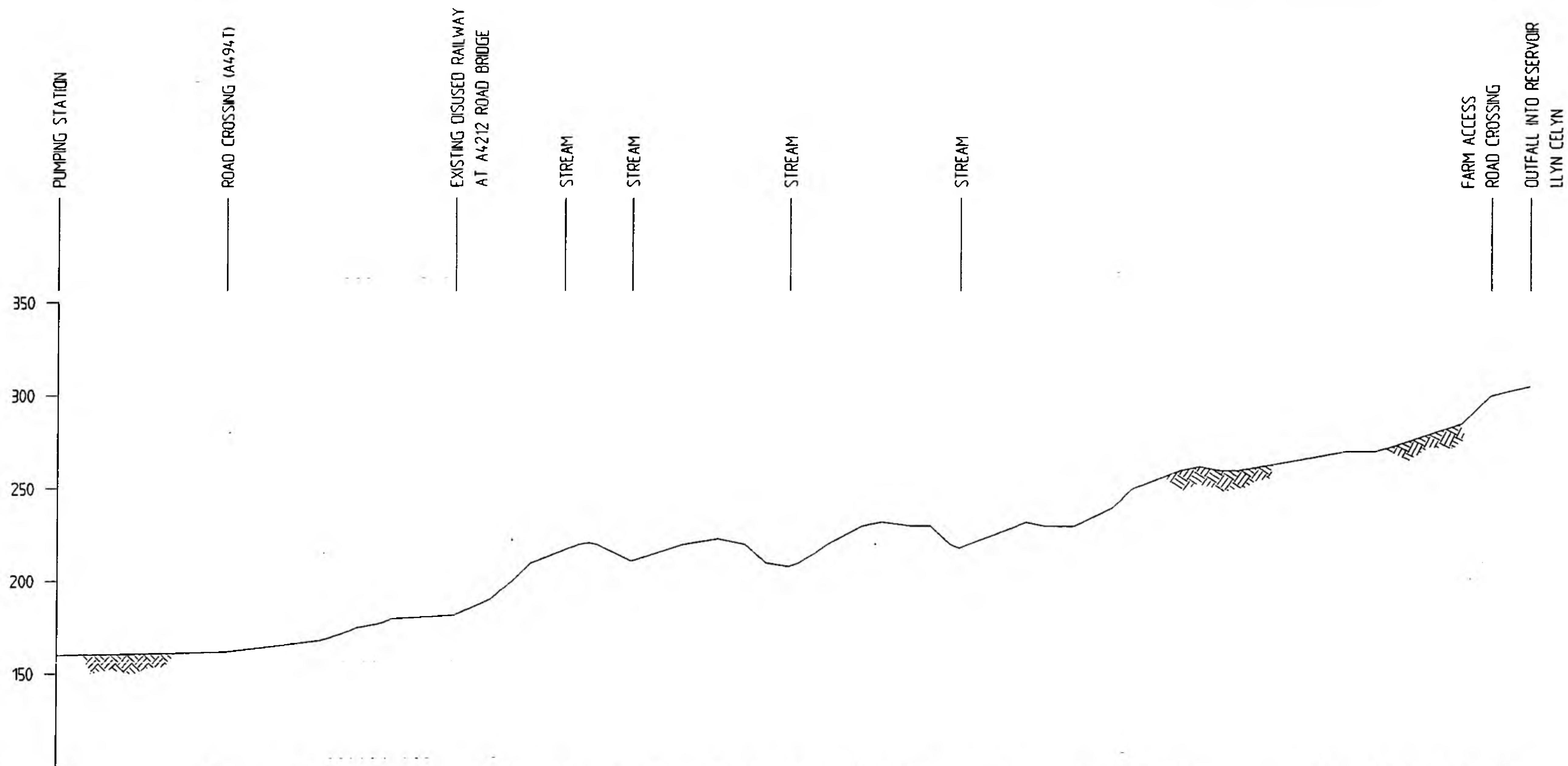


PLAN

SCALE 1 : 25 000

km 1 0 1 2 km

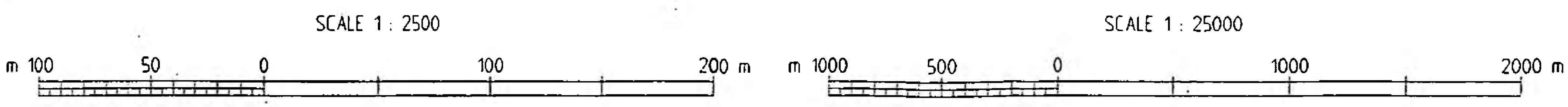
LLYN TEGID DUAL PUMPING SCHEME		
LLYN TEGID TO LLYN CELYN RESERVOIR PIPELINE ROUTE PLAN	Date: JAN.96	Drawing no. 5099/9/01



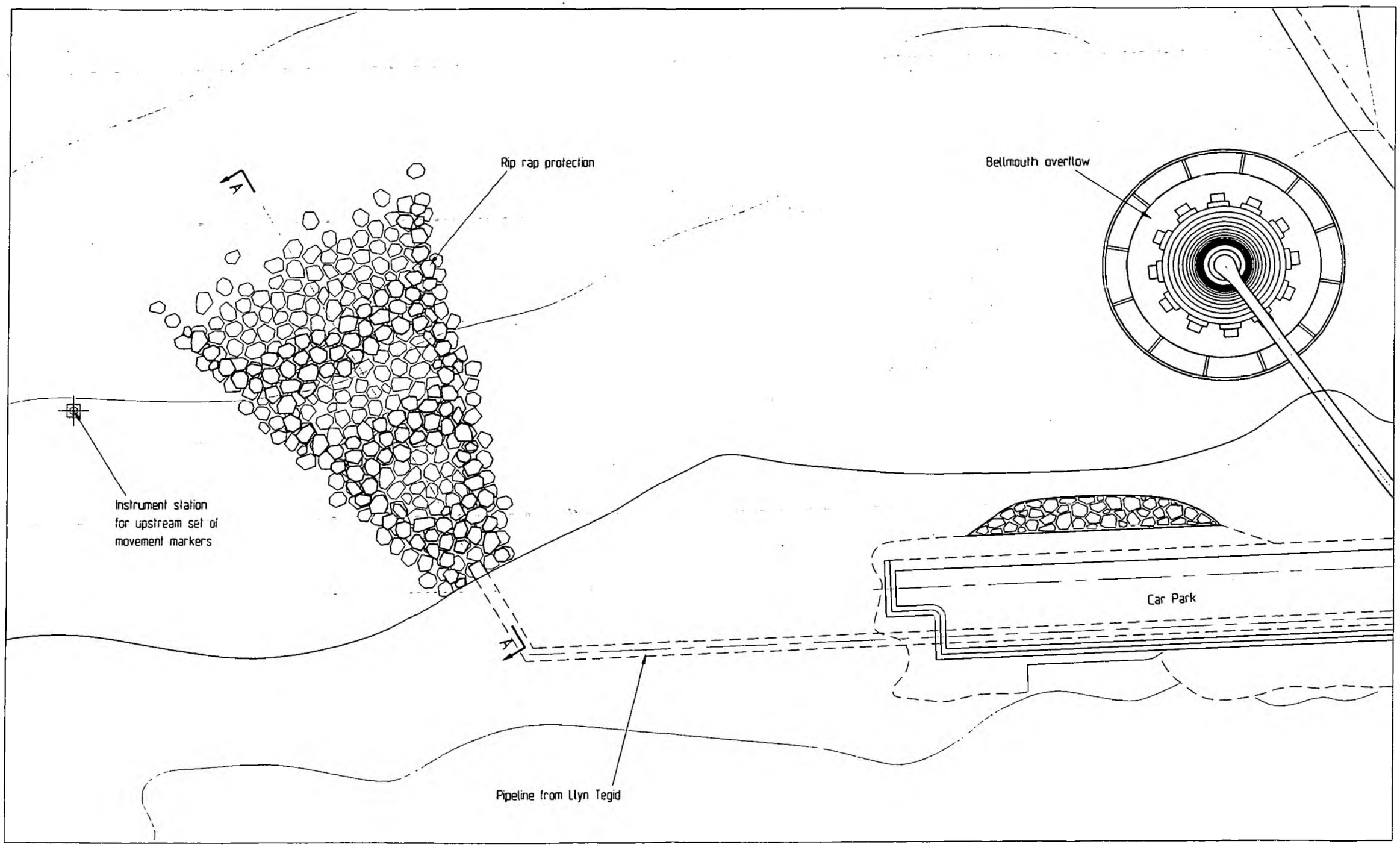
GROUND LEVEL (m AOD)	160	162	168	175	180	181	200	210	220	211	220	223	220	210	215	230	230	220	230	240	250	260	262	270	280	285	290	300	305	
INVERT LEVEL PIPE (m AOD)																														
GRADIENT																														
CHAINAGE (m)	0	900	1400	1600	1800	2000	2400	2520	2780	3050	3320	3500	3640	3750	4000	4250	4500	4700	5050	5550	5650	5900	6000	6750	7200	7350	7400	7500	7700	8000

HORIZONTAL SCALE 1:25000
VERTICAL SCALE 1:2500

LONGITUDINAL SECTION ALONG PIPELINE ROUTE



LLYN TEGID DUAL PUMPING SCHEME	
PROPOSED PIPELINE ROUTE LONGITUDINAL SECTION	Date: JAN.96
	Drawing no 5099/10/02



NOTE

1. For section A-A, see Drg. No. 5099/12/E.2

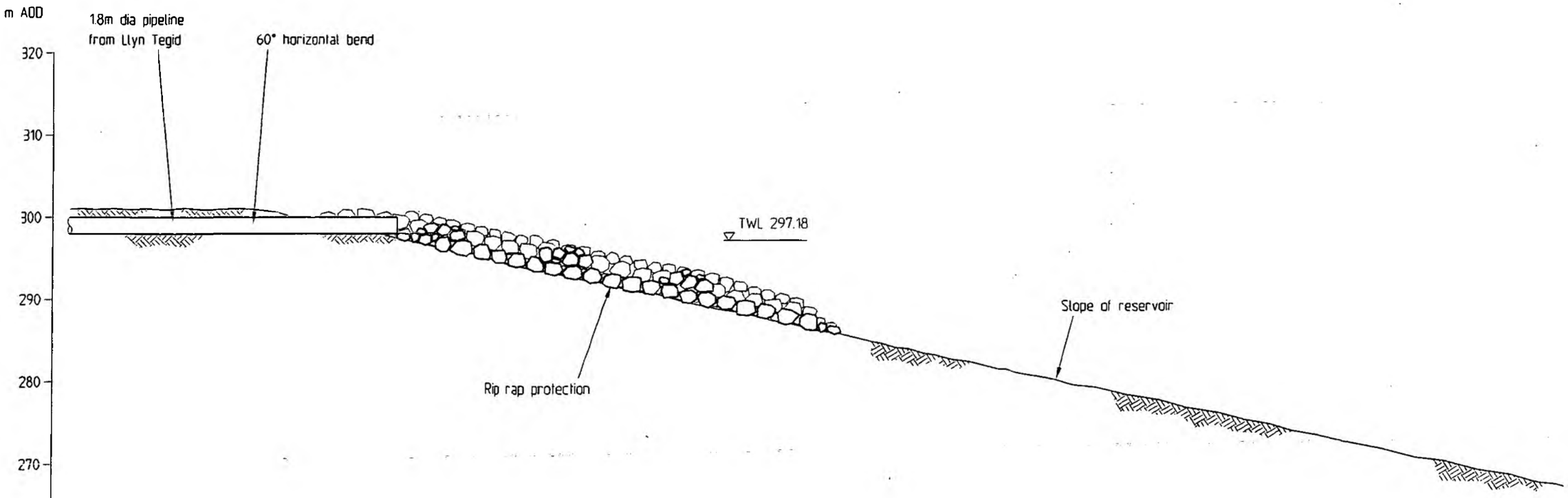
SCALE 1 : 500

m 10 0 10 20 50 m

PLAN ON INLET STRUCTURE

Scale 1:500

LLYN TEGID DUAL PUMPING SCHEME	
LLYN CELYN INLET PLAN	Date: JAN.96
	Drawing no. 5099/11/E.1



SECTION A-A
Scale 1:500

SCALE 1 : 500

metre 10 0 10 20 30 40 50 metres

LLYN TEGID DUAL PUMPING SCHEME	
LLYN CELYN INLET SECTION	Date: JAN.96
	Drawing no. 5099/12/E.2