Innovative Geosynthetic-Based Waste Water Treatment Systems

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ABSTRACT: Geosynthetic materials including geomembranes and geotextiles have been used extensively in waste water treatment systems as substitutes for conventional materials. This paper explores the potential for geomembrane materials to be a key element in developing new energy and resource efficient treatment technologies. The major element of these systems is an anaerobic lagoon process utilising geomembrane liners and geomembrane floating covers. These systems are energy and resource efficient in their operation and produce methane gas which is available for use as a renewable energy source. The paper describes the principles of these systems and presents a case study of a large anaerobic lagoon with a floating geomembrane cover and gas utilisation.

1.0 INTRODUCTION

Emerging industrial countries have a need to balance their rapid industrial development with appropriate environmental management to prevent land and water degradation that can arise from inadequate control of pollution and waste disposal. Traditional western technologies are often inappropriate and emerging industrial countries can benefit from sensible adaptation of appropriate new technologies.

Some of these areas are:

- Solid waste management using secure landfills
- Mine process storage and containment
- Mine Waste Tailings Disposal
- Waste water treatment utilising technologies such as covered anaerobic lagoons
- Water supply engineering including reservoirs, reservoir covers and treatment plants

This paper concentrates on the waste water treatment aspects based on the use of geosynthetic components to provide treatment plants for industrial and municipal waste waters that can be both cost effective and energy efficient in both established and emerging industrial regions.

2.0 WASTE WATER SYSTEMS

2.1 Parameters

The major parameters that we see influencing the selection of various process elements of waste water processing facilities in emerging industrial countries are as follows:

- Provide operational waste water treatment facilities that can be developed using appropriate technology utilising local skilled and unskilled personnel.
- Treat effluent from industrial and other sources to acceptable discharge standards with minimal operation costs and maximum use of waste material energy and other potential.
- Work within typical restrictions on land space, construction materials restrictions and power availability at these sites.
- Work within typical shortages of skilled labour such that the on-going operation of the plants should not require a high level of skills or technical development.
- Allow the adoption of more environmentally sustainable options.

2.2 Typical Plant

The basis of a typical plant is an initial anaerobic phase to provide primary treatment with gas and odour control and a second aerobic phase to provide further treatment to achieve the discharge standards required which will vary according to location and application.

The plant and process selection must be suitable and appropriate for the effluent to be treated and the capacity and needs of the local people. This means that additional weight should be given to such factors as:

- receiving waters and ceiling nutrient loadings
- economy of land space requirements
- potentially unreliable power supplies
- robust and simple processes, components and equipment
- availability of skilled operation and maintenance personnel
- end product utilisation
- climatic conditions

2.2.3 Anaerobic Lagoon

The initial treatment by anaerobic digestion can be achieved in an anaerobic lagoon fitted with a flexible membrane cover supplemented by gas collection and disposal or use as an energy source. Lagoons of this nature have been used by industrial effluent producers at various US and Australian locations and recently by Melbourne Water for a large municipal sewage lagoon at their Werribee Treatment Complex.

There are many variations possible ranging from relatively simple lagoon arrangements to which may be added circulation aids, heating or other additional features. The system is flexible and with proper material choices can be designed to allow future adjustments to capacity and performance if desired.

The major elements of an anaerobic lagoon will be as follows:

- Cut to fill earthworks to yield an earthen walled lagoon.
- An engineered synthetic liner to the lagoon base and walls to minimise leakage.
- A ballasted and tensioned synthetic membrane cover designed to float on the surface and control gas egress as well as manage storm water. Properly designed and built these structures have inherent structural stability and are extremely cost effective.
- A gas collection and handling system with gas disposal by venting, flaring or use as fuel.
- A capacity to provide gas storage to enable power generation as desired by economic considerations.

This type of anaerobic system is potentially attractive in Asia for reasons such as its relative simplicity, its lack of demand for quarry and concrete materials and the potential for renewable fuel creation. It requires considerably less land area than a typical facultative lagoon system of similar performance.

2.2.4 Aerobic Phase

In assessing the options for the aerobic second phase of treatment we suggest consideration of several options including:

- Aerobic Lagoon Process. Although operationally simple this is intensive in land use.
- Aerated Lagoon Process. This is less land use intensive but places greater demand on reliable power supply (which can be supplied by the anaerobic lagoon system) and skilled operation.
- Fixed Growth Reactor. This is the least demanding on land use and requires similar operator skill to aerated lagoons. They are an area of new and useful technology.

A Fixed Growth Reactor will produce sludge over extended periods of time which can initially be fed back to the anaerobic lagoon to later provide digested sludge for use in horticulture and similar areas.

3.0 POTENTIAL AREAS OF USE

The general waste water treatment concepts described can be designed and adapted for use to process many effluent streams of essentially organic origin. Some of these include:

- Agricultural enterprises such as piggeries, cattle feed lots etc
- Abattoirs and other meat processing enterprises
- Tanneries and similar processing of animal products
- Food processing plants
- Paper making plants
- Municipal and Industrial waste waters

4.0 CASE STUDY - WERRIBEE TREATMENT COMPLEX

The Werribee Sewage Treatment Complex on the outskirts of Melbourne is one of the most extensive farm and lagoon waste water treatment facilities in the world. It makes extensive use of grass filtration and large scale lagoon processes. Formerly in a rural location it is now being encroached upon by urban development which has lead to a program to reduce odour emissions. To additionally improve anaerobic efficiency and allow capture of methane gas for energy a floating flexible membrane cover has been installed over the anaerobic zone of one of the major treatment lagoons at the Werribee Treatment Complex.

This pioneering project is the first municipal waste water cover in Australia and with an area of some 3.5 hectares is the largest of its type in the world. Similar floating covers have been used for waste water treatment to industrial facilities but this is the first cover for municipal sewage treatment.

4.1 Lagoon Cover Program

Melbourne water had a desire to take existing anaerobic cover technology and develop it further for its needs related to large scale waste water treatment. Some of the particular areas of concern and interest were:

- Structural stability over a large lagoon subjected frequently to strong winds
- Failsafe operational security of the cover system and gas handling system
- Adequate service life expectation from the cover material in the face of the effluent and gas exposure and the UV radiation exposure as well as other environmental influences.
- The storage of methane gas under the cover so that advantage could be taken of electricity generation during peak hour tariff periods with the gas accumulated whilst grid electricity is used during off-peak times. This lead to a strong interest in systems and materials that offered gas storage potential.

In late 1991 Melbourne Water called tenders on a design and construct basis for a cover to the confined anaerobic zone of the 115E lagoon. This is the smallest of the lagoons in the cover program and the tender documents called for covers utilising High Density Polyethylene (HDPE). HDPE is a highly crystalline form of polyethylene and is known to have excellent UV and general chemical exposure characteristics.
It requires a suction restraint based design philosophy for such covers and this was recognised by the documents which also called for proposals that may enable gas storage now or in the future. The documents also called for a gas handling and flaring facility capable of drawing the gas off at a controlled suction and disposing of it by flaring and providing various instruments for evaluation of the gas production.

Plans were also made for the implementation of a power generation facility to operate on gas drawn from the gas handling facility, and to use the gas to provide heating to the anaerobic zone.

The design and construct contract for this work was let to Polyfelt Geosynthetics Pty Ltd with the HDPE liner material and associated cover design being provided by Gundle Linings Inc of Houston and the gas handling and flaring facility sub-contracted to Fluid Waste Treatment Pty Ltd.

4.2 The 115E Lagoon

The first pond of the 115E lagoon system is some 150 m wide and 1100 m long, 3 m deep and is oriented with the sewage inflow at the NNE end. It takes a winter inflow of around 55 ML/day of raw unscreened sewage which goes up to 75 ML/day in summer.

The cover is installed over the initial 230 m of its length which is the confined anaerobic zone. This area had already been separated from the aerobic zone by a floating boom type barrier. Surface aerators downstream of the floating barrier had created aerobic (non-odorous) conditions in the remainder of pond 1 and in the adjacent pond 2.

Prior to installation of the cover measurements had indicated that the uncovered anaerobic zone was reducing the BOD of the effluent from around 500 mg/l to 150 mg/l. The level of turbulence due to gas generation was found to be preventing sludge build up and the cover could be installed without need to consider future desludging of the covered anaerobic zone.

The lagoon embankments were built using compacted clay and were protected from wave action by rock armour beaching which required removal before construction of the cover. These embankments also provide access roadways for personnel and the roadway width reduction as a result of the cover installation was to be minimised.

The embankments were to provide fixing capacity on three sides of the pond and an alternative 'fourth wall' fixing method was required at the Southern end of the cover. This wall was permitted to be of structural or other construction provided it did nor allow gas escape and did not impede the flow of sewage down the pond.

4.3 Cover Design

The basic parameters specified for the cover design included the following:

- Maximum surface wind velocity 130 km/hr
- Ambient air temperature -5 ^{O}C to 45 ^{O}C
- Cover to operate generally under a slight vacuum or suction pressure
- Maximum gas production 20,000 cu.m/day
- Maximum fluctuation in floating cover level 100 mm.
- Service life guarantee on cover material of 15 years

The cover design is based on the use of 2.5 mm thick HDPE extruded liner material which is known to provide excellent long term exposed weathering performance and excellent chemical exposure resistance. The material density of HDPE is 0.94 and it therefore floats on water unaided.

In order to provide control over the cover shape and thereby control the flow of gas under the cover and the flow of surface storm water a skeletal system of ballast filled HDPE pipes with supplementary floats was fitted over the cover. The main longitudinal pipe is 315 mm dia and filled with cement slurry and the lateral pipes are 200 mm dia and filled with water. The lateral pipes are at a nominal 13.5 m spacing to correspond with every second seam in the 6.86m wide HDPE cover material and are anchored to concrete blocks set into the embankment crest. These pipes not only control the shape of the cover and allow storm water management but also provide additional ballasting potential against wind loadings particularly if the cover is allowed to partially inflate and store gas.

The weight pipe system directs gas flows to the lagoon batters to facilitate its collection by a peripheral pipe system under the cover at the batter crest which varies from 315 mm to 500 mm diameter. The three sides of the cover with batters are anchored and sealed by placing of the cover material into an anchor trench which is carefully backfilled with compacted clay.

The 'fourth wall' is achieved by a stayed cable system with floats and a 1.5 m deep skirt restrained by a slurry filled end pipe. Concrete anchorage points at the two 'fourth wall' corners required the embedment of HDPE sealing strips into the concrete.

The cover is intended for operation with a small internal vacuum maintained by external gas pumps and although some gas inflation for storage is possible a fully deflated condition must be maintained during periods of high winds.

Supplementary aspects of the design included the following:

- A storm water pump facility situated on the embankment away from the hazardous gas zone.
- Combined sampling/venting ports with a sliding pipe connection capable of controlling the maximum inflation of the cover in their immediate vicinity.
- Textured HDPE sheet walkways to provide strategic access.
- A gas collection pipe system sized to meet the needs of rapid drawdown in the face of an impending wind event if the cover is used for gas storage.

4.4 Cover Construction

In order to construct the cover over the operating anaerobic lagoon, use has been made of a temporary barge floating on top of the sludge. The barge has been used to support the cover as it is welded together in panels prior to moving the barge forward to the next position. This method enabled effective progressive anchoring of the cover against wind uplift as the work proceeded. During construction temporary gas extraction fans were used to draw gas from under the cover and exhaust it to air via a venting stack in a suitably remote location.

The cover construction was controlled using a contractor effected quality management system which exceeded the requirements of AS 2990 Category B. Most of the cover was welded together using hot wedge welding devices which produce a double weld with an internal air gap for integrity testing. Other welding was carried out with extrusion welding techniques. All of the welding was subjected to non-destructive evaluation involving either internal pressure or vacuum testing and strategic destructive test samples were taken under the direction of a third party quality auditor.

4.5 Gas Handling

A HDPE collection pipe system collects the gas from under the cover at the batter crests and this is connected to a stainless steel gas train and gas handling system at the Northern corner of the cover.

The gas handling system includes the following components:

- A duplicate gas pump/blower system to provide the suction to extract the gas and direct it through the system.
- A bypass to enable low gas flows to be handled without excessive suction fluctuation.
- Sedimentation and condensate traps to enable long term operation of the system.
- An LPG fired gas flare designed for use in exposed locations
- Sensors and instrumentation to enable constant evaluation of parameters such as suction pressure, flow rate and gas characteristics.
- An electronic control system to enable automatic control of the systems functions and transmission of data into the Werribee Treatment Complex telemetry system.

5. PIONEERS AND MURPHY

Murphy was the fellow who suggested that, particularly in critical circumstances, whatever can go wrong will go wrong. Irrespective of planning and forethought a pioneering project such as this can not be expected to escape unscathed from a few difficulties. Some of the difficulties faced on this project included:

- A build-up of semi-solid scum material under the cover which influences the gas production and behaviour and the surface water collection on top of the cover. Action to regulate inflow and apply gas sparging has lead to dissipation of much of this scum.
- Sensitivity of the functional behaviour and performance of the cover to small variations in under cover pressure differentials caused by atmospheric conditions.
- Inconsistent release of gas from under the cover particularly in periods of relatively low gas production. This can be partially attributed to a ballooning tendency seen to be a result of an excessive 'fullness' developed during construction.

In spite of these difficulties the cover is producing gas at a rate of around 10000 cu.m/day and although there is some undesirable distortion of the cover shape the gas handling train is able to handle this relatively unsteady gas flow without great difficulty. A 300 kVa generator facility has been connected to take gas from the cover and produce electricity and the gaseous fuel has the potential to run all of the aerators in the downstream aerobic zone.

6. CONCLUSIONS

Treatment systems based on geosynthetic anaerobic lagoon covers provide potential solutions to process and odour problems at both municipal and industrial waste water treatment facilities. As well as odour control they offer potential for improved anaerobic activity and gas utilisation in an energy conscious world. They can be combined with process facilities utilising geosynthetics to provide cost-effective waste water treatment systems which can be adapted to the needs of the emerging industrial world in a more environmentally sustainable fashion.

7. REFERENCES

Gulovsen, T., Hansen, P., Hutchison, D., Russell, J. and Scott, P. (1992) 'Odour Minimisation at Werribee' Australian Water and Wastewater Association Journal June.

Melbourne Water (1992) 'Contract No. 4524. Design, Supply Installation, Commissioning and Maintenance of a Floating Cover Gas Collection and Flaring Facilities on 115 East Lagoon at Werribee Treatment Complex.'

Sadlier, M. (1989) 'The Role of Synthetic Liners in Waste Management' Proceedings Fifth National Local Government Engineering Conference, Sydney.

Russell J. & Sadlier M. (1993) 'Design and Construction of a Synthetic Membrane Cover to a Large Active Sewage Treatment Lagoon'. 15th Australian Water and Wastewater Association Federal Convention, Gold Coast, Queensland.

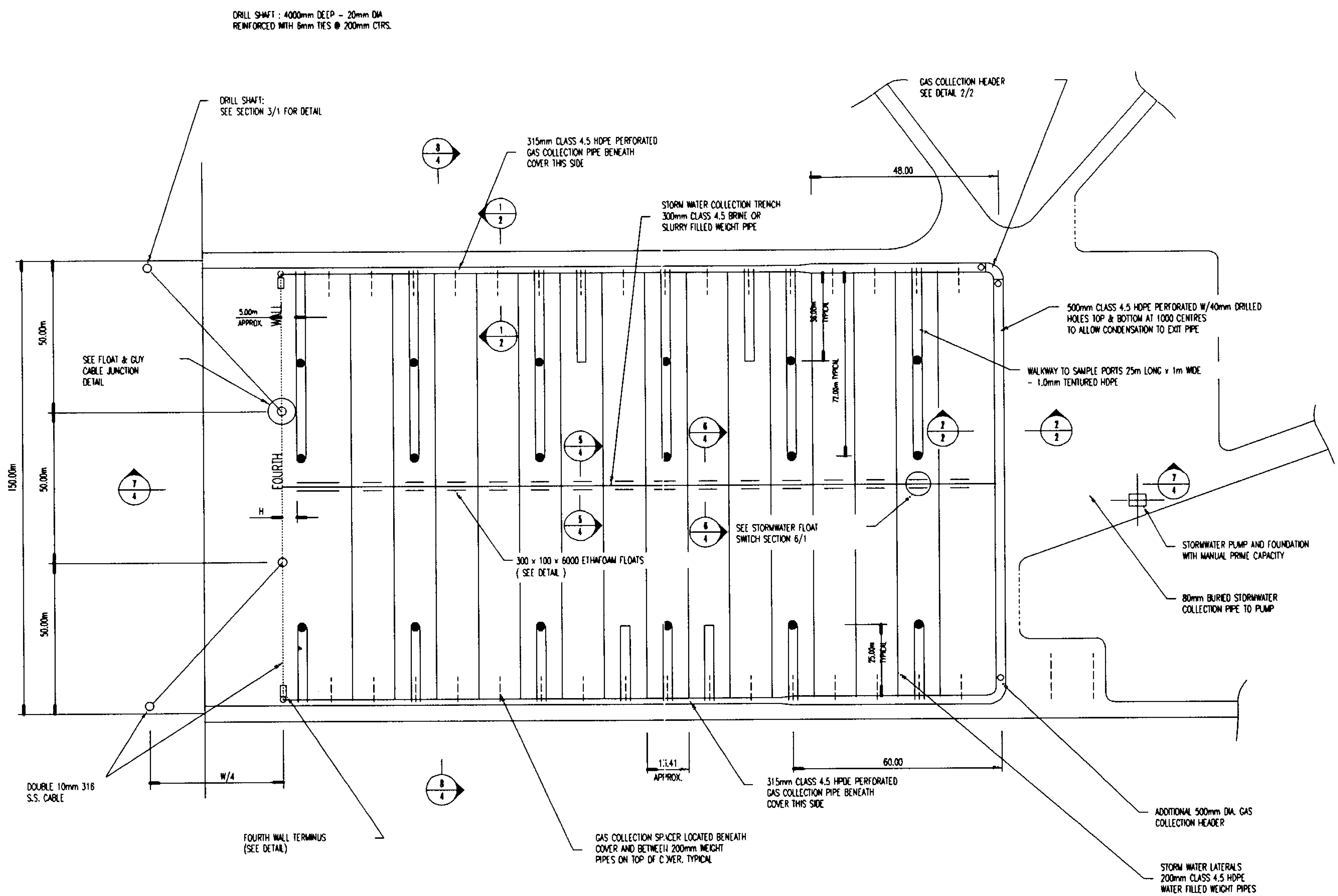

Figure 1. - Plan of Pond Cover