APPENDIX 4-8

DRAINAGE DESIGN REPORT

MWP

SEVEN HILLS WIND FARM
DYSART, COUNTY ROSCOMMON

Drainage Management Plan

Energia

April 2022

Contents

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21337	6006	C	22/04/2022	Brian Sayers	Sean Doyle	Brian Sayers	PLANNING

MWP, Engineering and Environmental Consultants
Address: Park House, Bessboro Road, Blackrock, Cork, T12 X251
www.mwp.ie

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1. Introduction

Energia is the developer for Seven Hills Wind Farm and Malachy Walsh and Partners (MWP) have been appointed to carry out the civil design for the project. Infrastructure for 20 no. wind turbine generators (WTGs) will be constructed as part of this project. The purpose of this document is to outline the design rationale for the drainage measures to be employed as part of the works.

2. Site description

The proposed site is split into two parts, with the Regional Road R363 separating 7 no. WTGs to north from the 13 no. WTGs to the south. The land is mostly agricultural on rolling hills. The geotechnical strata generally consist of clay, gravel or cobbles on rock. The ground is stable and suitable for access road and hardstand construction.

3. Drainage design

3.1 Design Principles

The drainage strategy for the wind farm site will ensure minimal impact on the existing flow regime, water quality, and run-off quantity.

The nature of the ground conditions dictates the drainage methodology that can be employed. On wet sites with soft ground, roads are dug down to a more solid bearing stratum and this results in a requirement for roadside drains where dirty water will accumulate. Where ground conditions are good, and the top surface is deemed suitable as a bearing stratum, roads can be constructed from that surface. This latter method does not result in a requirement for roadside drains.

Dirty water is generated on wind farm sites predominantly during construction. The dirty water is generated through movement of soil material around the site and breaking down of the road surface under sustained loading from construction traffic. Silt removal from dirty water runoff will be either by filtration or by means of settlement ponds as described below.

An important aspect of the treatment process is that clean water from outside the works area is not mixed with dirty water from within the works area. This minimises the quantity of water to be treated and consequently reduces the size and quantity of settlement ponds where they are used.

Clean water flows from the uphill side of catchments to the downhill side. Having this water pass through the works unimpeded reduces the risk of mixing with dirty water and ensures a smaller quantity of dirty water remains for treatment. Clean water will pass through roads of stone construction due to its porosity via overland flow. Separation of clean and dirty water drains is shown in Figure 2. Clean water cut-off drains will be provided on the uphill side of infrastructure where it is undesirable to have clean water enter the works. Such locations would be on the uphill side of material storage areas where overland flow is unlikely to pass through unimpeded and mixing with dirty water is likely to occur. These drains are routed through to the downhill side of the works and discharged through buffered outfalls.

Where drains are constructed they will incorporate a series of check dams that will attenuate the flow and provide storage for the increased runoff from exceptional rainfall events. Check dams will comprise a clean 100 mm to 150 mm crushed rock behind a Terram barrier that will be embedded into the base and sides of ditches by at least 100 mm.

3.1.1 Treatment by settlement ponds

A typical drainage design on a wind farm using settlement ponds is shown in Figure 1. The clean water interceptor drains are all positioned upslope to prevent any mixing of the clean and dirty water. The outflow from these drains is then piped under the road at suitable intervals and at low points depending on the site topography. In the illustration, dirty water drains collect all incident rainwater that falls on the infrastructure. This water then drains to settlement ponds for removal of sediment before it is discharged to the nearest watercourse.

Dewatering of turbine base excavations can result in significant flow rates to the drainage and settlement system if high-capacity pumps are used. Should pumping be required, temporary storage will be provided within the excavations and dewatering carried out at a flow rate that is within the capacity of the settlement ponds.

The outflow from the treatment system will be infiltrated into the ground via swales at the end of the settlement ponds.

The details of the water treatment process and calculations for the required size of the settlement ponds is included in Section 4 of this document.

Figure 1 – Typical drainage design

Figure 2 – Separation of clean and dirty water drainage on wind farm site

3.1.2 Treatment by filtration

A key mitigation available for the development of this wind farm is through the use of existing vegetation to filter and clean dirty water run-off. As ground conditions here are optimal roads can be constructed on a geotextile material laid out on the existing surface without the need to carry out any excavations. This approach is highly beneficial for a number of reasons:

- It reduces the amount of excavations and soil movement around the site;
- It allows clean water to pass from uphill to downhill unimpeded;
- It eliminates the requirement for settlement ponds;
- It eliminates the concentration of dirty water at discrete locations and ensures treatment at the point of dirty water generation.

The last point is a fundamental principle of the drainage management to be employed on this site. Dirty water drains convey large amounts of water to discrete points where settlement ponds treat this water prior to discharge. However, a more efficient and sustainable method for treatment of dirty water is to utilise the massive filtration capacity of the vegetation immediately adjacent to infrastructure to filter suspended material from water as it passes through. Some of this water infiltrates into the ground and the remainder, if any, runs off to the nearest watercourse downhill. This methodology has been used very successfully where it has been employed and it ensures no ponding of dirty water and efficient filtration of sediment. Examples of this are shown in Figure 3 and Figure 4.

Figure 3 – Road built on existing surface without dirty water drains (1)

Figure 4 – Road built on existing surface without dirty water drains (2)

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3.2 Water quality management

Sediment such as clay, or silt could potentially cause significant pollution during the construction phase of the wind farm due to the erosion of exposed soil by surface water runoff. The water quality management system has been prepared in order to control erosion and prevent sediment runoff during the construction phase of the wind farm. The implementation of sediment and erosion control measures is essential in preventing sediment pollution. The system was designed having regard to:

- Knowledge of the site's environmental conditions
- Previous construction experience of wind farm developments in similar environments
- Previous experience of environmental constraints and issues from construction of wind farms in similar environmental conditions
- Technical guidance and best management practice manuals

The following site-specific information was used in the design of the drainage and treatment system:

- High resolution aerial photography and topographical surveys
- Wind farm infrastructure layout (turbines, service roads and ancillary development)
- Hydrology maps (watercourses and buffer zones)
- Soil and land use maps
- Met Éireann point rainfall frequency data

The settlement ponds and check dams described previously provide the essential mechanism for the removal of silt from construction-related runoff and the controlled return of the treated surface waters to infiltrate to the ground.

The drainage and treatment system will ensure that the construction and early post-construction phases of the wind farm will not create adverse effects on the aquatic environment that could compromise the ability to meet Water Framework Directive objectives or fulfil compliance with basic measures required including the Nitrates Directive, the Habitats and Birds Directives and the Drinking Water Directive.

3.3 Water quality control measures

Additional infrastructure and measures used to control water quality are described in the following sub-sections.

3.3.1 Minimise exposed areas

The area of exposed ground will be kept to a minimum by maintaining where possible existing vegetation that would otherwise be subject to erosion in the vicinity of the internal wind farm roads and other infrastructure. The clearing of topsoil will be delayed until just before construction begins rather than stripping the entire site months in advance particularly during road construction.

3.3.2 Exposed formation

Where formation level requires excavation to bedrock (such as at hardstands or WTG foundations) measures will be taken to limit vertical flow of water into the bedrock from the works. At WTG foundations sand blinding, DPM and concrete blinding will be provided at formation level to create a vertical cut-off barrier and to mitigate the risk of concrete leakage into the ground below. Hardstands will be underlain with a layer of Terram geotextile to act in the same fashion.

3.3.3 Establish vegetation

Exposed areas of the site will need to be re-vegetated either by natural regeneration or by reseeding. Natural regeneration relies on colonisation of bare ground by native species from adjacent habitats. For this method, a roughened surface will be provided that can trap seeds and soil to provide initial regeneration areas.

3.3.4 Road construction and maintenance

On-site experience in wind farm construction and forestry development across the country has shown that the single most effective method of reducing the volume of sediment created by construction is the immediate surfacing of all service roads with high quality, hard wearing crushed aggregate graded transversely to one or both sides. In this regard, 100mm of imported Cl.804 will be provided as a finished surface. This significantly reduces the level of suspended solids in the storm water runoff.

The road surface can become contaminated with clay or other silty material during construction. Road cleaning will, therefore, need to be undertaken regularly during wet weather to reduce the volume of sediment runoff to the treatment system. This is normally achieved by scraping the road surface with the front bucket of an excavator and disposing of the material at designated locations within the site.

3.3.5 Check dams

Check dams will be placed at regular intervals, based on gradient, along all drains to provide flow attenuation, slow down runoff to promote settlement and to reduce scour and ditch erosion. They will be placed at appropriate intervals and heights, depending on the drain gradient, to allow small pools to develop behind them. These will contain a clean 100 mm to 150 mm stone material.

Figure 5 – Example of check dams along roadside drainage channels

3.4 Inspection and maintenance

The drainage and treatment system for the proposed wind farm must be managed and monitored at all times and particularly after heavy rainfall events during the construction phase. The drainage and treatment system will be regularly inspected and maintained to ensure that any failures are quickly identified and repaired so as to prevent water pollution. A programme of inspection and maintenance should be designed by the contractor and dedicated construction personnel assigned to manage this programme. A checklist of the inspection and maintenance control measures should be developed by the contractor and records kept of inspections and maintenance works. These drainage controls should be kept in place during the operational phase of the wind farm until the vegetation is re-established.

This checklist would include the following :

- Condition of silt traps and settlement ponds
- Removal of silt from settlement ponds
- Erosion concerns
- Blockages of cross-drains

3.5 Weather monitoring

Weather monitoring is a key input to the successful management of the drainage and treatment system during the construction of the wind farm. This, at a minimum, will involve 24-hour advance meteorological forecasting (Met Éireann download) linked to a trigger-response system. When a pre-determined rainfall trigger level is exceeded (e.g. 1 in 5 year storm event), planned responses should be undertaken. These responses will involve control measures including the cessation of construction until the storm event has passed over and flood flows have subsided. Dedicated construction personnel should be assigned to monitor weather.

3.6 Water quality monitoring

A programme for water monitoring should be prepared in consultation with Inland Fisheries Ireland (IFI) prior to the commencement of the construction of the wind farm. The plan should include monitoring of water during the pre-, throughout and post construction phases. Further baseline water quality monitoring of all streams near the development site should be undertaken prior to construction. During the construction phase of the project, water quality in the turloughs and wells, and outflow from the drainage and attenuation system should be monitored, field-tested and laboratory tested on a regular basis during different weather conditions. This monitoring together with the visual monitoring will help to ensure that the mitigation measures that are in place to protect water quality are working effectively.

3.7 Operational phase

The measures for control of runoff and sediment relate to the construction phase of the project when there is a high volume of site vehicles and delivery vehicles moving around the wind farm site. Following construction, the amount of on-site traffic will be negligible and there will be no particular risk of sediment runoff. Runoff from the roads, hardstands, and other works areas will continue to be directed to the settlement ponds, which will be left in place. Check dams within the drainage channels will remain in place. The retention of this part of the drainage infrastructure will ensure that runoff continues to be attenuated and dispersed across existing vegetation before recharge into the ground.

4. Settlement ponds

4.1 Treatment process

The treatment process consists of primary, secondary and tertiary treatment as follows:

- The *primary treatment* consists of a two-chamber settlement pond. The adoption of a two-chambered settlement pond facilitates the regular maintenance of the ponds in a controlled manner preventing the release of sediment during cleaning, a commonly overlooked problem with single chamber designs.
- The water then passes through a *secondary treatment* system in the form of a graded stone filter bed.
- The outflow is then channelled into a swale where infiltration into the ground takes place. This is the final or *tertiary stage* of the treatment process.

Drains carrying construction site runoff will be diverted into settlement ponds that reduce flow velocities, allowing silt to settle and reducing the sediment loading. A modular approach has been adopted for the design of the settlement ponds which have been sized to cater for a 1,200 m² works area. This is equivalent to a road length of 250 metres or the area of a typical turbine base and crane hard standing.

The ponds will have a modular surface area of 30 m^2. Where larger areas have to be catered for, the pond area will increase pro-rata. The settlement capacity is independent of depth; however, a nominal depth of 1.00 metres will be used to allow for storage of settled material. The length to width ratio will be at least 5:1 to encourage uniform flow across the cross-section of the pond and to avoid short-circuiting of the flow.

The settlement ponds have two chambers arranged in series. The first chamber has a maximum length of three metres and allows rapid settlement of the heavier particles that make up most of the suspended solid mass. The second chamber is the main settlement areas where the smaller particles are allowed to settle. The chambers are separated by a mound of drainage stone through which the flow from the first chamber migrates. This allows the flow to enter the chambers across its full cross-section so that it can operate efficiently in accordance with its design principles.

- The settlement ponds have been designed with regard to the following:
- Met Éireann Point Rainfall Frequency data (statistical rainfall intensity / duration table)
- Runoff flow rate for the modular catchment area
- Character of the impermeable areas (runoff coefficients)
- Design particle size and density

Settlement ponds will require regular inspection and cleaning when necessary. This will be carried out under low or zero flow conditions so as not to contaminate the clean effluent from the pond. The water level will first be lowered to a minimum level by pumping without disturbing the settled sediment. The sediment will then be removed by mechanical excavator and disposed of in areas designated for deposition of spoil. Settlement ponds will require perimeter fencing and signage to ensure that there are no health and safety risks to workers or landowners.

4.2 Settlement pond calculations

Generally, high intensity rainfall events have a short duration and lower intensity rainfall events tend to have a longer duration. The Met Éireann Extreme Rainfall Data for the area demonstrates that the chance of occurrence of a storm event of a given duration decreases (higher return period) as intensity increases. For a given return period the total depth of rainfall increases with storm duration but the actual rainfall rate over that period of time decreases.

For the operation of the settlement ponds it is the rate of flow rather than the total rainfall that is relevant. The return period is a measure of the likelihood that a storm of a particular intensity will occur in a given year. However, it is important to note that the chances of occurrence of a storm event with a particular return period are the same in each year but should on average occur once in that time-period. For instance, a storm event at the wind farm site with an intensity of 30.4 mm/hour and 60-minute duration would be expected to occur once in a 100-year period. This is more appropriately expressed as an annual exceedance probability (AEP) of 1%; that is, it has a 1% chance of being equalled or exceeded in any year.

The runoff control measures for the wind farm site have been designed in the context of storm events of varying duration and intensity. The settlement ponds have been designed to cater for a maximum continuous flow rate associated with a medium-intensity rainfall event. Higher intensity runoff will be attenuated by the open drain collection system which provides temporary storage and limits the rate at which it enters the settlement ponds. This is achieved by the use of check dams within the open drains as described elsewhere in this document. Longer duration storms of 24 hours or more generally have very low intensity and are not critical in terms of the runoff rates that they generate.

The temporary settlement ponds have been designed to ensure that the suspended solids concentration at the outlet will be less than 25 mg/l (Threshold Limit). The ponds are designed to operate effectively for the runoff rate associated with a continuous high rainfall rate of 28.4 mm/hour. This is equivalent to a 30-minute duration storm event with a 10-year return period (M10-30) taken from the Met Éireann Point Rainfall Frequency table for the site location. This is considered a statistically significant rainfall event in the context of the length of time it takes to construct a wind farm.

The design runoff rate is calculated using the equation:

$Q = c\ i\ A$

where c is the runoff coefficient

i is the rainfall intensity in m/sec and

A is the catchment surface area in m^2.

A runoff coefficient of 0.70 is assumed for the hardcore surface. For a rainfall intensity of 28.4 mm/hour and a catchment area of 1,200m^2 the runoff rate is:

$Q = 0.70 \times (0.0284/3600) \times 1{,}200\ m^3/sec$

$= 0.0066\ m^3/sec$ (6.60 litres/sec)

The main design parameter for the settlement pond is the water surface area. The required surface area is the design flow rate in m^3/sec divided by the particle settlement velocity (V_s) in m/sec (Area = $Q/V_s\ m^2$).

The particle settlement velocity is determined using the Stokes equation as follows:

$V_s = 2\ r^2\ (D_p - D_f) / (9\ n)$

where V_s is the particle settlement velocity (m/sec)

r is the radius of the particle (metres),

D_p is the density of the particles (kg/m^3);

D_f is the density of the fluid (kg/m^3),

n is the viscosity of the fluid (0.000133 kg sec/m^2 @ 10°C).

For a particle density of 2,400kg/m^3, water density of 1,000kg/m^3 and particle diameter of 20 microns (radius 10^5 metres) the settlement velocity, V_s, is:

$V_s = 2 \times (10^{-5})^2 \times (2{,}400 - 1{,}000) / (9 \times 0.000133)$

$= 2 \times 10^{-10} \times 1{,}400 / 0.001197$

$= 0.000234$ m/sec.

The required settlement pond surface area is

A_p = Q/V_s

= 0.0066/0.000234

= 28.20 m^2

Theoretically the pond depth is not relevant but in practice a minimum depth is required to ensure laminar flow and to allow temporary storage of settled silt. The modular settlement pond has been designed with a surface area of 30 m^2 and a depth of 1m. In practice it has been found that most of the settlement occurs in the first chamber with very low turbidity levels being achieved in the final effluent.

Where temporary settlement ponds are located next to turbine foundation excavations that are dewatered using a pump, the flow rate from the pumps will be limited to 6.60 litres/sec.

For practical reasons it may be necessary to increase the runoff area directed to a settlement pond in which case the pond surface area will be increased pro-rata.