Appendix 8.5: Outline Drainage Strategy

Pell Frischmann

Dunside Wind Farm

Outline Drainage Strategy

EIA Report Appendix 8.5

Introduction

Pell Frischmann have been commissioned by LUC (referred to as the “Client” throughout the document) to provide an outline Drainage Strategy for the proposed Dunside Wind Farm (referred to as the “Proposed Development” throughout the document), on behalf of EDF Energy Renewables Limited.

This report provides an outline surface water management strategy to mitigate any impact from surface water runoff attributed to the Proposed Development. The strategy is developed in accordance with sustainable drainage principles and allows the Site to mitigate flood risk during design storm events, whilst ensuring no increase of flood risk to offsite receptors and avoiding deterioration of the water environment.

The drainage strategy presented in this document has been developed to demonstrate measures that could be used across the Site to protect the existing hydrological regime. Examples of mitigation measures are provided throughout the report with detailed proposals for measures to be documented prior to construction. Measures will provide the same or greater protection for the water environment. The measures are designed to be proportionate to the risk and, where greater risk is highlighted at specific locations prior to construction, specific measures would be agreed for those locations.

The drainage strategy has been prepared in accordance with the advice and requirements prescribed in current best practice documents relating to management of flood risk in development, published by the Construction Industry Research and Information Association (CIRIA)[1], the British Standards Institution (BSI) BS8533[2] and Scottish Environment Protection Agency (SEPA) National Standing Advice on Development and Flood Risk[3].

The Site is within the jurisdiction of Scottish Borders Council (SBC).

To complete the Drainage Strategy, the following key stages of work have been undertaken:

- Collation of desk-based information and a review of publicly available information, including local data, policy and guidance.
- A desktop review of other data that has been made available such as topographical surveys/elevation information and Proposed Development layout options.
- Estimation of the required surface water attenuation storage and provision of outline Sustainable Urban Drainage Systems (SuDS) features arrangement.

Background and Site Context

The Proposed Development is located to the north of Westruther in the Scottish Borders Council administrative area. The site is located adjacent to the operational Fallago Rig Wind Farm as shown on Figure 1.

[1] CIRIA Drainage Guidance can be found here: https://www.susdrain.org/resources/ciria-guidance.html
[2] Information on BSI 8533 can be found here: https://knowledge.bsigroup.com/products/assessing-and-managing-flood-risk-in-development-code-of-practice/standard
[3] SEPA National Standing Advice: https://www.sepa.org.uk/media/535237/sepa-standing-advice-for-planning-authorities-and-developers-lups-gu8-v11-web.pdf

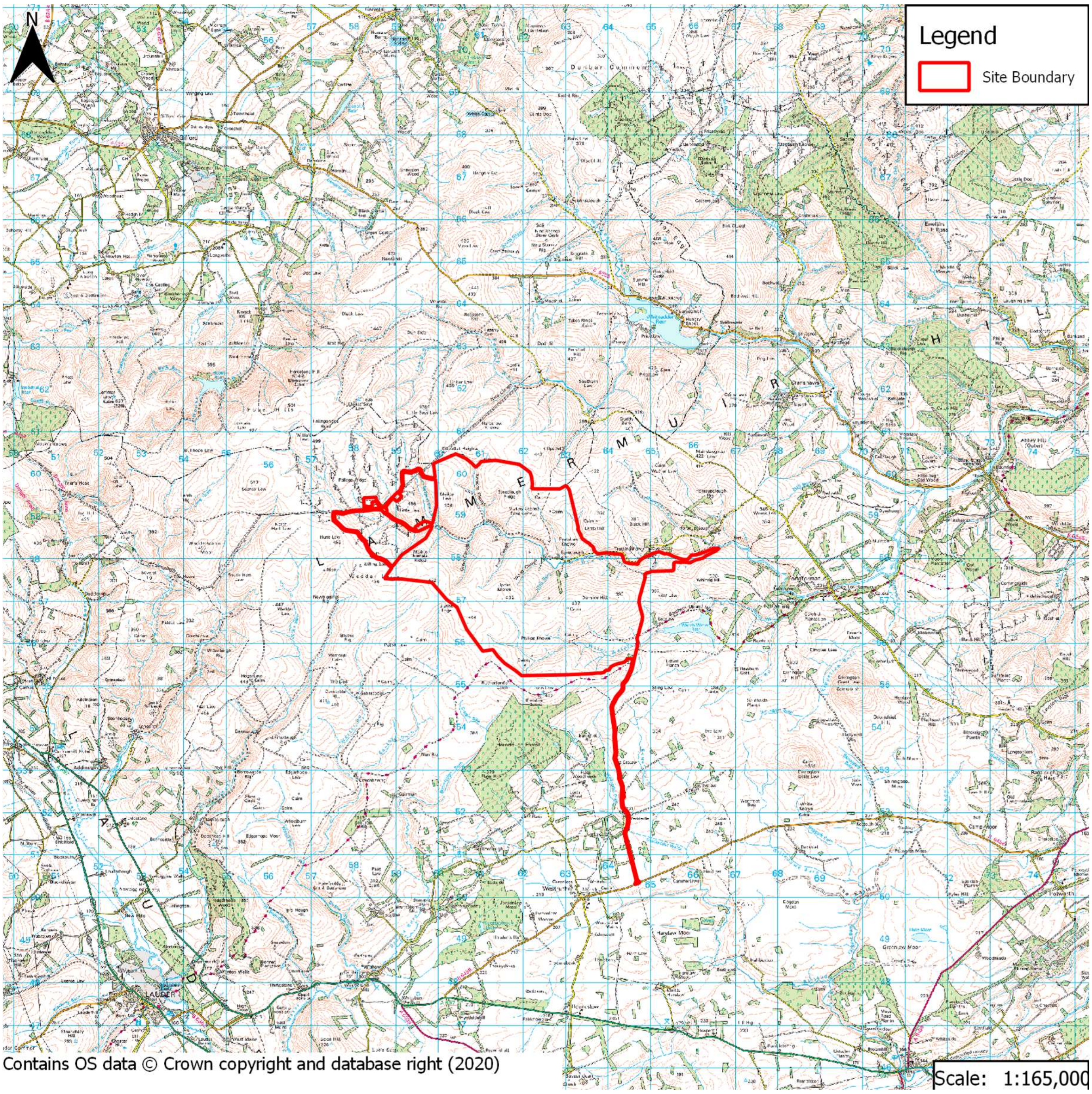

Figure 1 Site Location Plan

Proposed Development

The Proposed Development comprises of up to 15 wind turbines, an expansion to an existing substation compound, approximately 14.6 km of proposed wind farm tracks, 1.1 km of light vehicle tracks and other ancillary infrastructure, within a total site area of approximately 2006 ha.

Local Watercourses

The main watercourse within the proposed Site boundary is the Dye Water, which flows in an easterly direction through the centre of the Site.

The Dye Water valley is surrounded by adjacent summits which comprise a series of rounded hilltops aligned roughly from west to east, producing pronounced undulating topography along each side of the valley. Numerous small named and unnamed watercourses (e.g., Burn betwixt the Laws, Kersons Cleugh, Green Cleugh, Foul Cleugh, Wood Cleugh and Hall Cleugh) flow from these hills towards the Dye Water, resulting in several defined hill spurs on either side of the valley. Figure 2 shows the extent of existing watercourses crossed by the infrastructure and Figure 3 shows the location of the existing and proposed crossings. A full plan of the site, watercourse crossings and catchments is shown in Appendix A

Kaya Consulting (KC) have undertaken a hydrological analysis for each individual catchment at the watercourse crossing location, determining the design flows for 2-, 10-, 30-, 50-, 100- and 200-year return periods.

4 new watercourse crossings will be required over the identified watercourses as a result of the Proposed Development. The watercourse crossing specification and capacity check is provided in Appendix B.

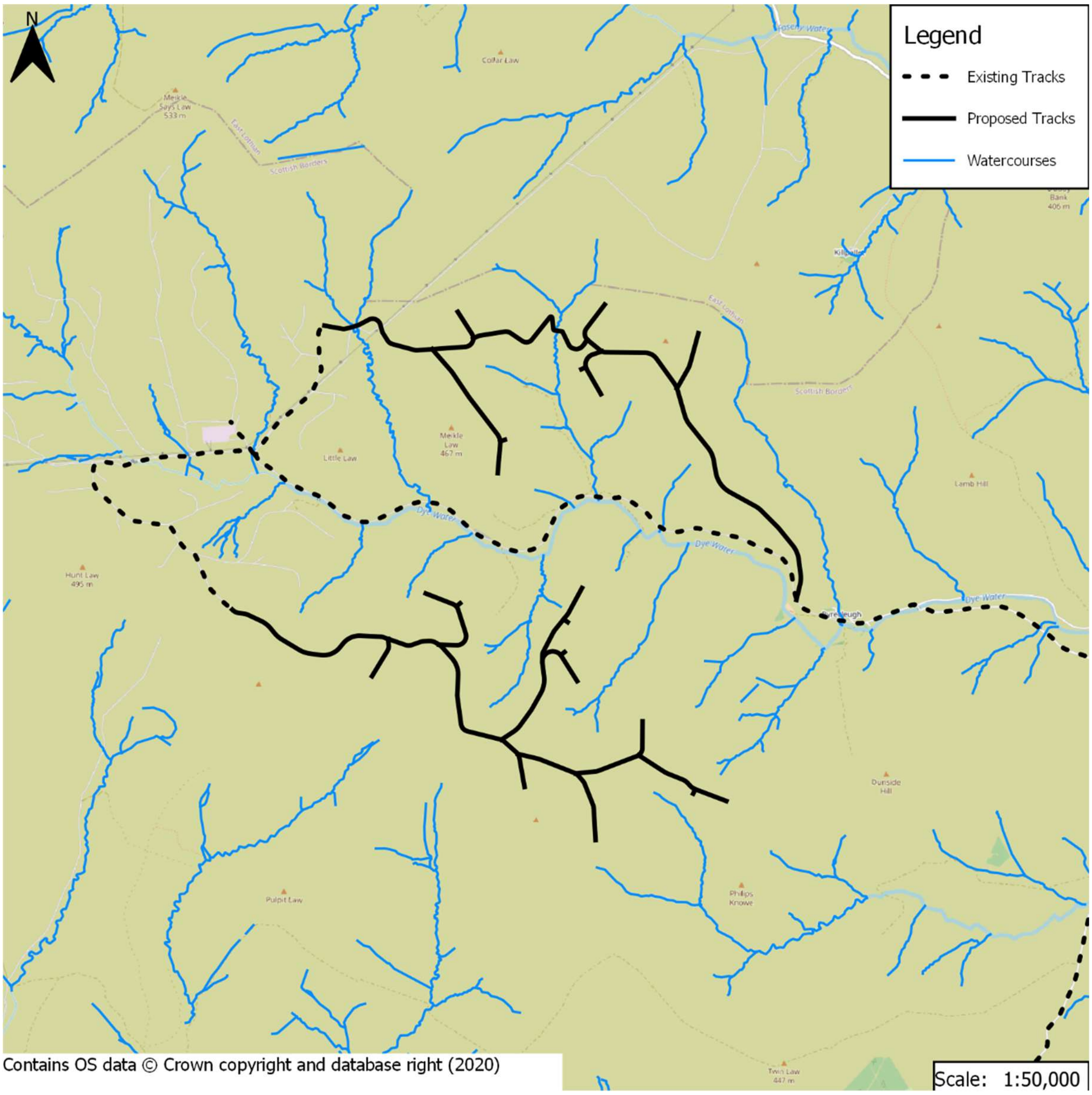

Figure 2 Existing Watercourses

Topography

The topography varies over the site, with a central valley from east to west associated with the Dye Water. The Proposed Development is generally split across three main topographically distinct areas (north-west, north-east and south), comprising separate high points or ridges. There are a number of steep slopes within the site, generally located in the vicinity of watercourses.

Trackside Drainage

The proposed trackside drainage layout for the Proposed Development is shown in Drawings SK01-SK06 (Appendix C).

The ditches will be sized by the contractor at the detailed design stage to accommodate surface runoff from the track for the 1 in 30-year design storm event.

All permanent drainage should be installed concurrently with all adjacent infrastructure.

All drainage channels should be sufficiently wide as is practicable to allow wildlife to safely enter and exit the channel. The channel banks shall be at a minimum slope of 1 in 3.

Permanent check dams should be specified at the detailed design stage. They should be spaced at regular intervals within the drainage ditches. Check dams are required to reduce the velocity and slow down sediment transportation while also preventing channel scour.

Check dams are proposed to be constructed of clean aggregate graded 50mm-300mm and embedded into the side walls and invert of the excavation by at least 100mm. The number and location of check dams will be dependent on the slope gradient with a minimum spacing of 1 check dam per 75m length of ditch.

The spacing of relief drains crossing the access tracks should be determined at the detailed design stage. The spacing of relief drains should not exceed 200m as per best practice.

Watercourse Crossings

There are 4 new/upgraded watercourse crossings required for the Proposed Development (2 existing crossings which will require upgrading and 2 proposed new crossings) There are an additional 19 existing crossings where no upgrading is required).

Design Criteria

The watercourse crossing outline design is based on the following guidance:

- SEPA River Crossings Engineering in the water environment: good practice guide.[4]
- CIRIA The SuDS Manual C753.[5]

In addition, SBC's response to the EIA Scoping submission requested that:

1. *"The formation of any newly formed hard surfaces such as access roads should be attenuated to at least existing Greenfield runoff rates so that there is no increased effect on downstream receptors. Likewise, any discharges from SUDS and other drainage should be kept to existing Greenfield runoff rates.*
2. *If there are to be any culverts, watercourse crossings or alterations to crossings, these must not reduce the flow conveyance of the watercourse.*
3. *Details of the silt traps and any other functions that the applicant proposes to minimise the amount of sediment entering the watercourse should be submitted."*

SEPA has recommended that all small-scale watercourse crossings should be designed as oversized bottomless arched culverts or traditional style bridges within their scoping response.

[4] SEPA River Crossings Engineering in the Water Environment: Good Practice Guide can be found here: https://www.sepa.org.uk/media/151036/wat-sg-25.pdf
[5] CIRIA The SuDS Manual C753 can be found here: https://www.ciria.org/ItemDetail?iProductCode=C753&

Methodology

The location of the watercourse crossings is based on KC's assessment.

The ground elevations within the Site boundary are informed from publicly available LiDAR data which was used for approximation of the watercourses cross-section and slope.

The method for sizing the watercourse crossings included:

1. Estimating the length of the hydraulic structure, based on satellite imagery, LiDAR data with 50cm resolution, basic dimensions of watercourse collected on site, hydrological characteristics and the extents of the proposed infrastructure.
2. Estimating the slope of the structure, based on upstream and downstream invert levels, informed from LiDAR data.
3. Sizing the structure based on the above parameters and the requirement to convey the 1 in 200-year return period flows, with capacity verified with HY-8 Culvert Hydraulic Analysis Programme for all specified bottomless arch culverts.

The method provides reasonable estimation. The exact slope, however, will require to be assessed on site by the contractor.

Watercourse Crossing Outline Design

The full results, including the HY-8 capacity check output, for all watercourse crossings are provided in Appendix B. The following is a summary of the watercourse crossing outline design:

- New Watercourse Crossing 1 is located towards the south-western edge of the Site Boundary and is proposed to be a bottomless arch culvert with span of 1.829m and rise of 0.546m
- Upgraded Watercourse Crossing 2 is located just upstream of the Burn betwixt the Laws and consists of two structures. Crossing 2a is a bottomless arch culvert on the Middle Black Burn and Watercourse Crossing 2b is a bottomless arch culvert on Black Burn. Both culverts are with a span of 2.438m and rise of 0.889m.
- New Watercourse Crossing 3 is located on the unnamed drain along Kersons Cleugh and is proposed to be a bottomless arch culvert with span of 2.438m and rise of 1.016m.

Figure 3 shows a plan of the proposed watercourse crossing locations.

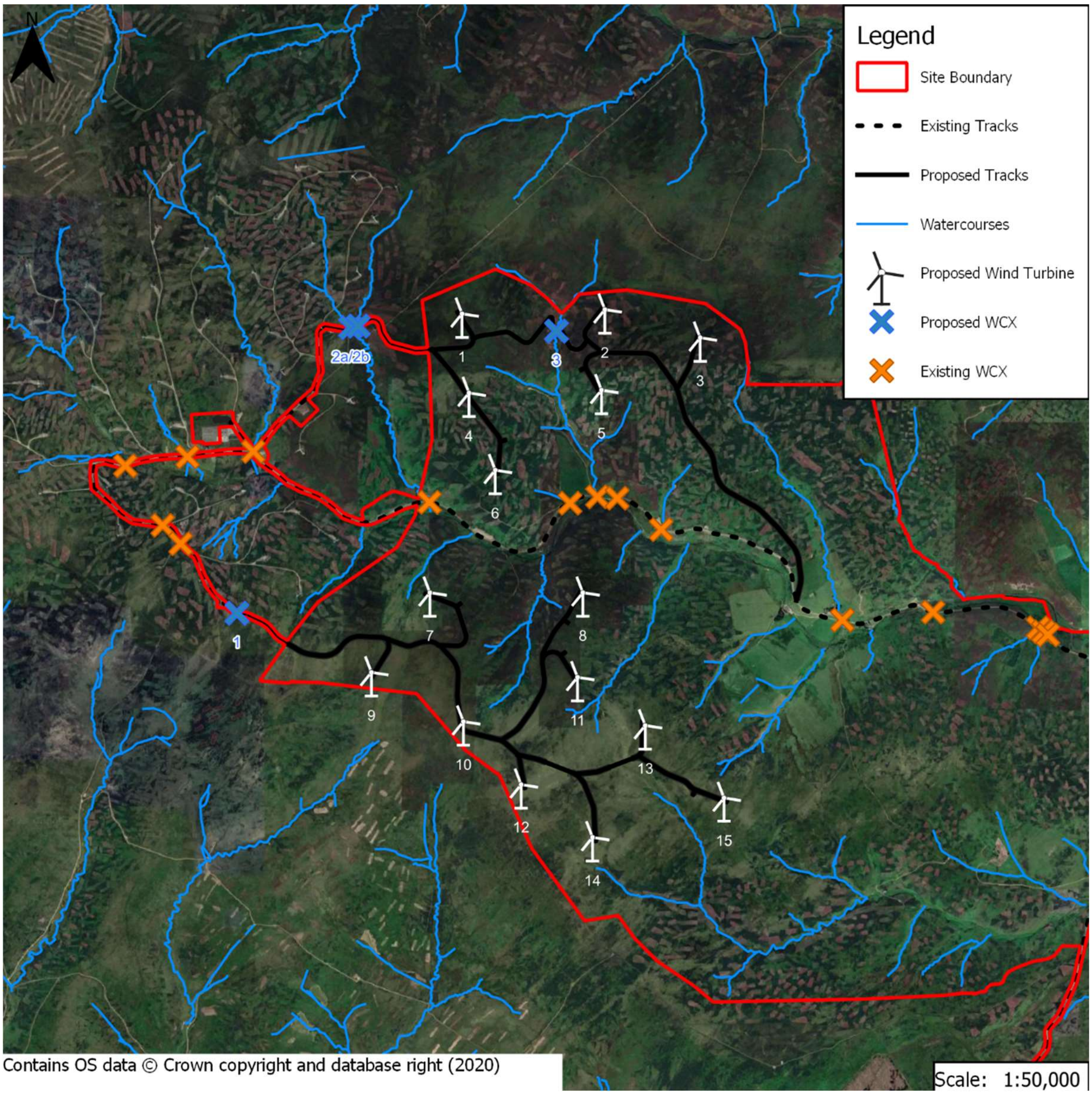

Figure 3 Watercourse Crossing Locations

The proposed bottomless arch culverts will have to incorporate concrete structural protection to account for the abnormal loadings and mitigate against structural failure. The concrete surround specification will be determined at the detailed design stage of the project.

The proposed watercourse crossings should be laid in natural ground or into the bed of the watercourse where applicable. All culvert sizes have been designed to maintain self-cleansing velocity during the design event (1 in 200-year return period).

Flow Attenuation

Current best practice relating to sustainable surface water management is outlined in the SuDS Manual (CIRIA Report C753) which provides details on the use of SuDS for managing surface water runoff:

- Prevention – the use of good site design and housekeeping measures on individual sites to prevent runoff and pollution (e.g. minimise areas of hard standing).

- Source Control – control of runoff at or very near its source (such as the use of rainwater harvesting, permeable paving or green roofs).
- Site Control – management of water from several sub-catchments (including routing water from roofs and car parks to one or several soakaways or attenuation ponds for the whole site).
- Regional Control – management of runoff from several sites, typically in a retention pond or wetland.

It is generally accepted that implementation of SuDS, as opposed to conventional drainage systems, provides several benefits by:

- Reducing peak flows to watercourses or sewers and potentially reducing the risk of flooding downstream. Reducing the volumes and frequency of water flowing directly to watercourses or sewers by removing pollutants from diffuse pollutant sources.

- Improving water quality over conventional surface water sewers by removing pollutants from diffuse pollutant sources.

- Reducing potable water demand through rainwater harvesting.

- Improving amenity through the provision of public open spaces and providing biodiversity and wildlife habitat enhancements.

- Replicating natural drainage patterns, including the recharge of groundwater so that the baseflows are maintained.

The Surface Water Drainage Strategy for the Proposed Development will comprise the management of surface water runoff from the hardstanding and roof areas.

In accordance with CIRIA Report C753, the hierarchy for favoured disposal of surface water runoff from development sites is as follows:

1. Water reuse, where a demand is identified.
2. Infiltration to Ground, where ground conditions permit.
3. Discharge to Surface Waters.
4. Discharge to Sewer.

Proposed Surface Drainage

The additional permanent impermeable areas within the Proposed Development consist of the substation platform extension and the turbine hardstanding areas. They will consist of compacted gravel. The drainage design is based on a conservative assumption that they are 80% impermeable.

Greenfield runoff rates have been estimated through application of methodology outlined in IH124 as set out within the Interim Code of Practice for SuDS (ICPSuDS). The IH124 method can be used to estimate Greenfield runoff rates for a range of Annual Exceedance Probability (AEP) events, or return periods by applying regional growth curve factors to the mean annual peak runoff (i.e. QBAR). The UK hydrological region for the Site is Region 2 therefore the appropriate growth curve factors for this region have been incorporated into the analysis undertaken in the MicroDrainage software suite.

The hydrological characteristics for the catchment have been incorporated into the runoff modelling and results are presented below in Table 1 for a range of AEP storm events.

- Site Area: Substation Platform – 1.3ha; Turbine hardstanding – 0.24ha
- Average Annual Rainfall (SAAR): 953
- Soil Index: 0.50
- UK Hydrological Region: No.2
- Urban Extent: 0

Table 1 Estimation of Greenfield (pre-development) Rate of Runoff

AEP (%)	Return Period	Greenfield Runoff Rate (l/s/ha)
50	2	7.2
	QBAR	7.9
3.3	30	15
1	100	20.8
0.5	200	23.6
0.1	1000	30.5

The QBAR 'Unit Greenfield Runoff Rate' for the Site, and thus the limiting post development peak runoff rate for all storm events up to and including the design 0.5% AEP plus climate change, has been estimated to be 7.9l/s/ha.

Therefore, the limiting Greenfield runoff rate, assuming 80% impermeability is **8.2l/s** for the substation platform and **1.5l/s** for a wind turbine hardstanding.

Proposed Attenuation and SuDS Features

Based on the attenuation calculations, undertaken in MicroDrainage (Appendix D), a volume of 903m^3 need to be attenuated for the substation platform extension for the 0.5% AEP + uplift for climate change. It is proposed that this is attenuated via a SuDS attenuation pond with the following parameters:

- 1.35m total depth
- 300mm freeboard allowance
- 1 in 3 side slope
- Outflow controlled via a Hydro-brake

It is recommended that an emergency spillway is designed at the detailed design stage for the proposed SuDS pond to accommodate for a storm event exceeding 0.5% AEP + climate change.

Due to the site topography and the location of the proposed substation platform, the SuDS pond outfall will be to the south or southwest of the site. The location of outfall pipe will be confirmed following consent through the detailed drainage management strategy as per the CEMP.

For the turbine hardstanding areas, it is proposed that interception drains are placed at the downslope of the wind turbine platforms, intercepting and attenuating runoff. Discharge of surface water would be achieved by water spilling over a designed weir section along the crest of the drain with appropriate erosion protection. This attenuation method is considered most suitable for the rural upland area of the Site. The required attenuation volume per turbine hardstanding area for the 0.5% AEP + uplift for climate change is 165.8m^3 and was calculated through Innovyze MicroDrainage (shown in Appendix C).

The latest guidance on climate change impacts on peak rainfall intensities has been published by SEPA, with an updated approach based on regional estimates across river management catchments. The site falls within the Tweed Catchment, which suggests for the 2080s epoch the climate change allowance is 35%.

Summary & Recommendations

Summary of outline drainage strategy for the site:

- The Site contains 14.6km of proposed access tracks. The proposed access tracks will be served by a network of surface water drainage ditches adjacent to the tracks. The trackside drainage will utilise relief drains crossing the access track longitudinally to ensure the drainage ditches do not surcharge.
- The proposed drains should utilise silt traps/catch pits at the inlet of all cross drains to prevent the pipes becoming blocked.
- The proposed trackside drainage should be designed so that it allows wildlife to cross safely.
- Erosion protection should be utilised at all inlets and outlets
- 4 proposed watercourse crossings have been sized and specified on the basis of hydrological assessment undertaken by KC, LiDAR data and the proposed infrastructure layout (two upgraded crossings and two new crossings).
- All of the proposed watercourse crossing are bottomless arch culverts.
- 2 of the proposed watercourse crossings are replacing existing conventional closed pipe culverts on the Middle Black Burn and the Black Burn.
- It is proposed that runoff from the proposed substation platform and the wind turbine hardstandings is attenuated by cut-off drains at the downslope side of the platforms. Runoff would then be discharged overland towards the downstream catchment.

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Rev	Suit	Description	Date	Originator	Checker	Approver
P01	S01	First Issue	14-Jun-23	K.Ivanov	R Lucey	S.McGarva

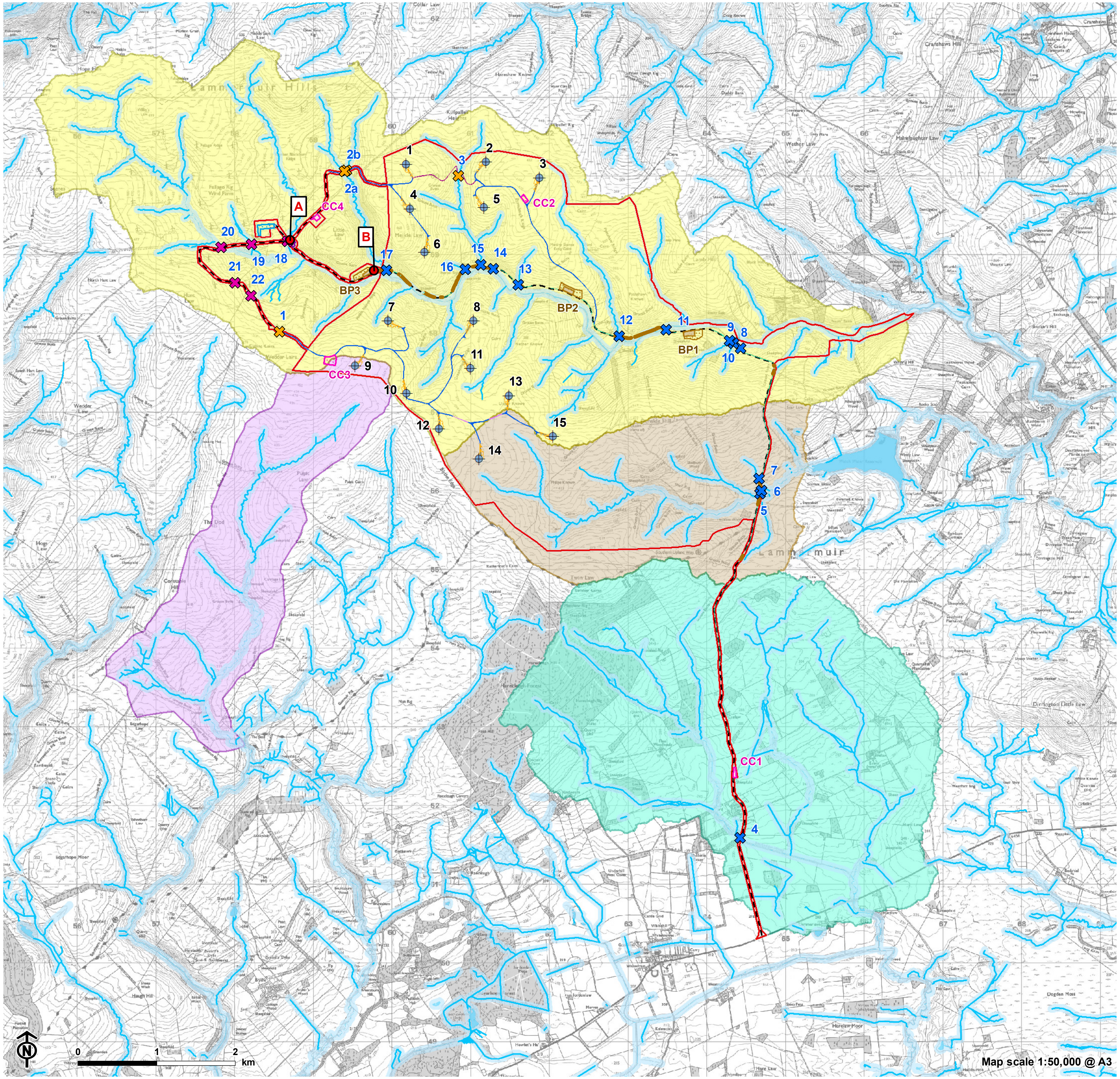
Ref. reference. Rev revision. Suit suitability.

Appendix A Watercourses, Buffers, Catchments and Watercourse Crossings Plan

Dunside Wind Farm
for EDF Renewables

LUC

Figure 8.2: Watercourses, buffers, catchments and watercourse crossings (Existing and Proposed)



- Turbine
- Site Boundary
- Substation extension
- Construction compound
- Existing construction compound
- Borrow pit
- Borrow pit search area
- Temporary hardstanding
- Permanent hardstanding
- Battery storage
- Proposed new track (floating)
- Proposed new track
- Proposed light vehicle track (3m wide)
- Proposed existing track upgrade
- Existing track

Watercourse crossings

- Proposed
- Existing access track
- Existing wind farm track

Locations of watercourse buffer encroachment

- 50m buffer encroachment A and B
- 50m buffer encroachment C

Catchment areas

- Dye Water Catchment
- Wester Burn catchment
- Watch Water catchment
- Blackadder Catchment
- Watercourses and surface water
- 50m buffer from surface water features

KAYA CONSULTING

EDF renewables

CB:SR EB:robertson_s LUC FIG08_02_11838_r0_Catchments_A3L 25/05/2023
Source: EDF, Kaya

Appendix B Proposed Culvert Capacity Check with HY-8

Watercourse Crossing 1 Culvert Properties

Crossing Properties

Name: Crossing 1

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	0.230	cms
Design Flow	0.260	cms
Maximum Flow	0.300	cms
TAILWATER DATA		
Channel Type	Rectangular Channel	
Bottom Width	2.000	m
Channel Slope	0.0467	m/m
Manning's n (channel)	0.035	
Channel Invert Elevation	456.400	m
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	m
Crest Length	2.000	m
Crest Elevation	458.000	m
Roadway Surface	Gravel	
Top Width	6.000	m

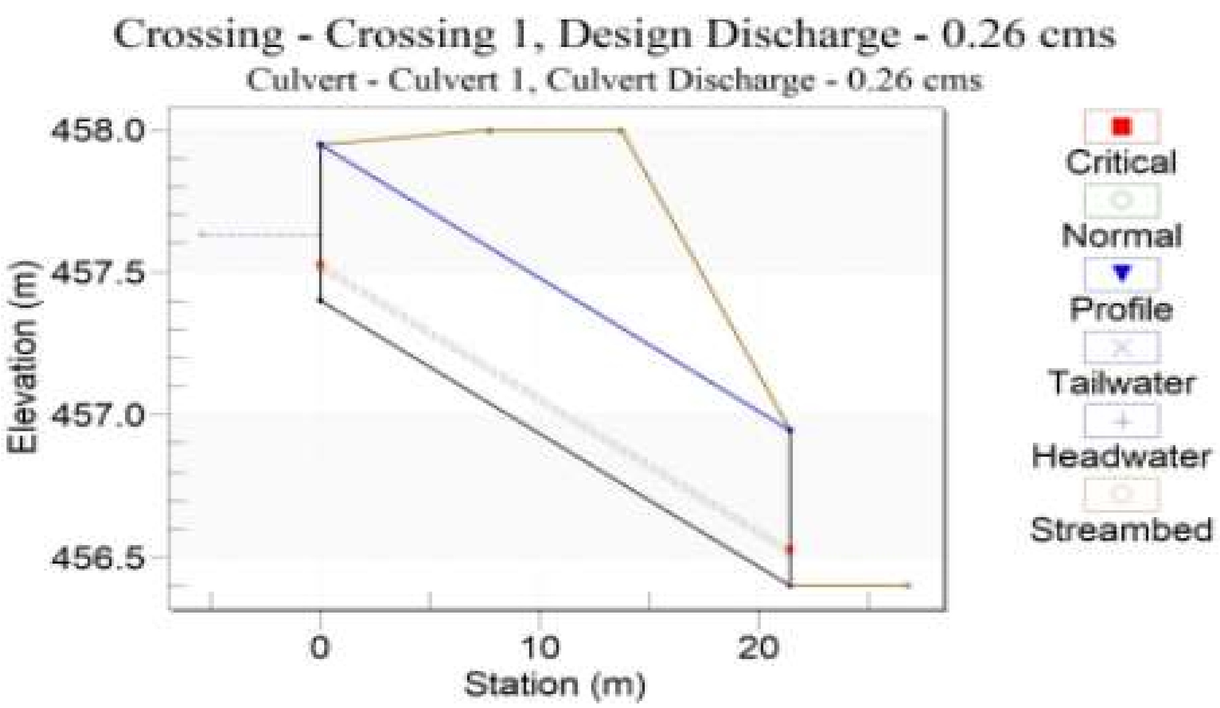
Culvert Properties

Culvert 1

Add Culvert
Duplicate Culvert
Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Arch, Open Bottom	
Material	Corrugated Steel	
Size	Define...	
Span	1.829	m
Rise	0.546	m
Embedment Depth	0.000	mm
Manning's n (Top/Sides)	0.020	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting (Ke=0.9)	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	m
Inlet Elevation	457.400	m
Outlet Station	21.430	m
Outlet Elevation	456.400	m

Watercourse Crossing 1 Design Discharge



Watercourse Crossing 1 Summary Table

Headwater Elevation (m)	Total Discharge (cms)	Culvert 1 Discharge (cms)	Roadway Discharge (cms)	Iterations
457.61	0.23	0.23	0.00	1
457.62	0.24	0.24	0.00	1
457.62	0.24	0.24	0.00	1
457.63	0.25	0.25	0.00	1
457.63	0.26	0.26	0.00	1
457.64	0.27	0.27	0.00	1
457.64	0.27	0.27	0.00	1
457.64	0.28	0.28	0.00	1
457.65	0.29	0.29	0.00	1
457.65	0.29	0.29	0.00	1
457.66	0.30	0.30	0.00	1
458.00	0.88	0.88	0.00	Overtopping

Watercourse Crossing 2a Culvert Properties

Crossing Properties

Name: Crossing 2a

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	2.000	cms
Design Flow	2.340	cms
Maximum Flow	2.500	cms
TAILWATER DATA		
Channel Type	Rectangular Channel	
Bottom Width	2.000	m
Channel Slope	0.0533	m/m
Manning's n (channel)	0.035	
Channel Invert Elevation	388.700	m
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	m
Crest Length	2.000	m
Crest Elevation	390.500	m
Roadway Surface	Gravel	
Top Width	6.000	m

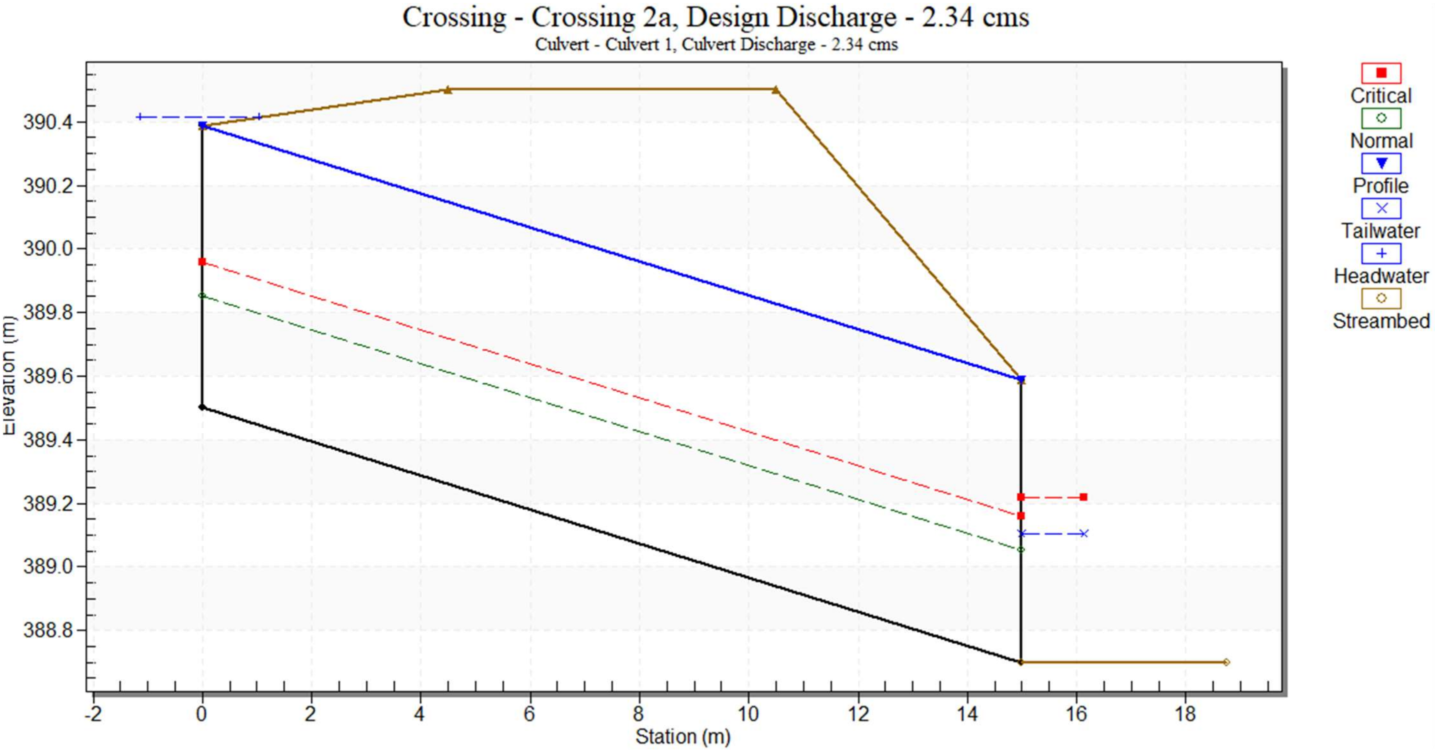
Culvert Properties

Culvert 1

Add Culvert
Duplicate Culvert
Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Arch, Open Bottom	
Material	Corrugated Steel	
Size	Define...	
Span	2.438	m
Rise	0.889	m
Embedment Depth	0.000	mm
Manning's n (Top/Sides)	0.020	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting (Ke=0.9)	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	m
Inlet Elevation	389.500	m
Outlet Station	15.000	m
Outlet Elevation	388.700	m

Watercourse Crossing 2a Design Discharge



Watercourse Crossing 2a Summary Table

Headwater Elevation (m)	Total Discharge (cms)	Culvert 1 Discharge (cms)	Roadway Discharge (cms)	Iterations
390.31	2.00	2.00	0.00	1
390.32	2.05	2.05	0.00	1
390.34	2.10	2.10	0.00	1
390.35	2.15	2.15	0.00	1
390.37	2.20	2.20	0.00	1
390.39	2.25	2.25	0.00	1
390.40	2.30	2.30	0.00	1
390.41	2.34	2.34	0.00	1
390.43	2.40	2.40	0.00	1
390.45	2.45	2.45	0.00	1
390.47	2.50	2.50	0.00	1
390.50	2.60	2.60	0.00	Overtopping

Watercourse Crossing 2b Culvert Properties

Crossing Properties

Name: Crossing 2b

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	2.000	cms
Design Flow	2.520	cms
Maximum Flow	2.600	cms
TAILWATER DATA		
Channel Type	Rectangular Channel	
Bottom Width	2.000	m
Channel Slope	0.0533	m/m
Manning's n (channel)	0.035	
Channel Invert Elevation	388.700	m
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	m
Crest Length	2.000	m
Crest Elevation	390.500	m
Roadway Surface	Gravel	
Top Width	6.000	m

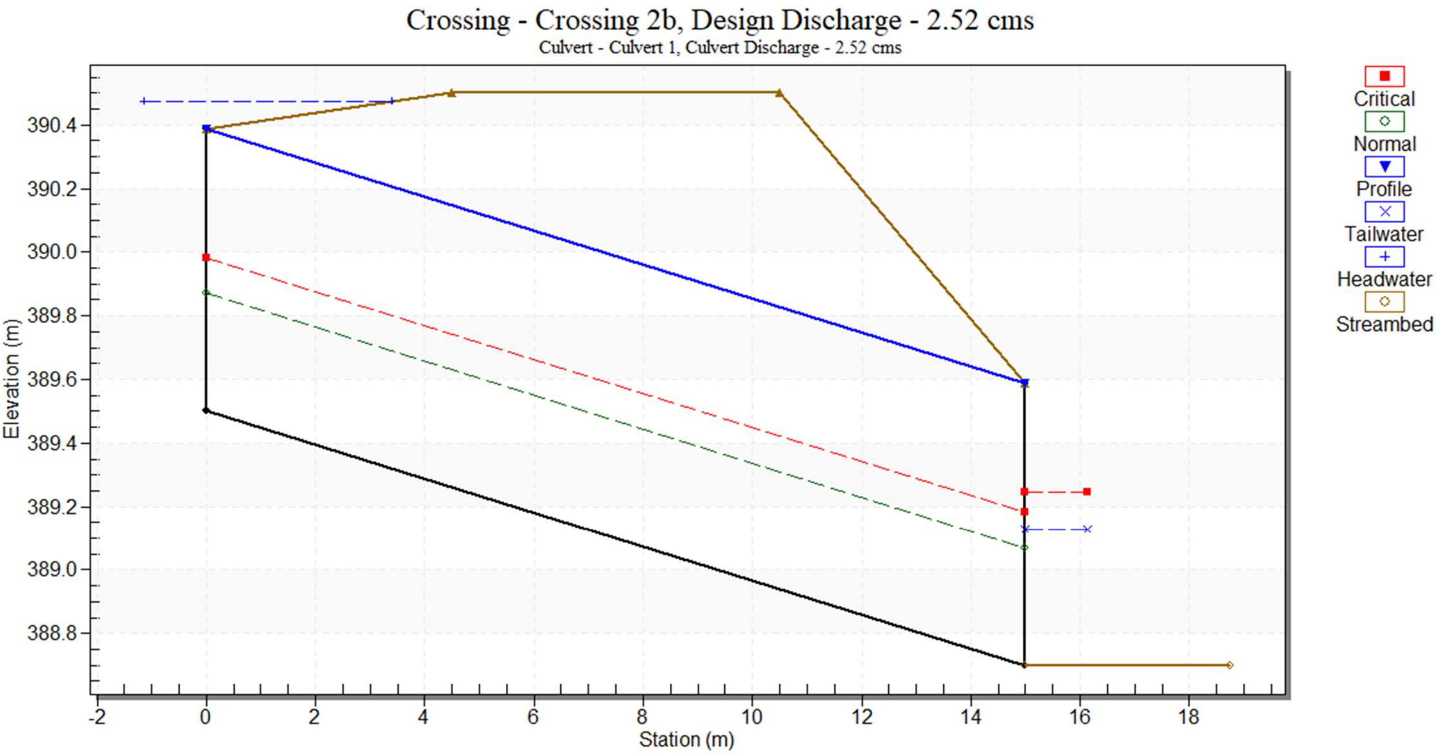
Culvert Properties

Culvert 1

Add Culvert | Duplicate Culvert | Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Arch, Open Bottom	
Material	Corrugated Steel	
Size	Define...	
Span	2.438	m
Rise	0.889	m
Embedment Depth	0.000	mm
Manning's n (Top/Sides)	0.020	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting (Ke=0.9)	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	m
Inlet Elevation	389.500	m
Outlet Station	15.000	m
Outlet Elevation	388.700	m

Watercourse Crossing 2b Design Discharge



Watercourse Crossing 2b Summary Table

Headwater Elevation (m)	Total Discharge (cms)	Culvert 1 Discharge (cms)	Roadway Discharge (cms)	Iterations
390.31	2.00	2.00	0.00	1
390.32	2.06	2.06	0.00	1
390.34	2.12	2.12	0.00	1
390.36	2.18	2.18	0.00	1
390.38	2.24	2.24	0.00	1
390.40	2.30	2.30	0.00	1
390.42	2.36	2.36	0.00	1
390.44	2.42	2.42	0.00	1
390.46	2.48	2.48	0.00	1
390.47	2.52	2.52	0.00	1
390.50	2.60	2.60	0.00	1
390.50	2.60	2.60	0.00	Overtopping

Watercourse Crossing 3 Culvert Properties

Crossing Properties

Name: Crossing 3

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	3.010	cms
Design Flow	3.490	cms
Maximum Flow	3.600	cms
TAILWATER DATA		
Channel Type	Rectangular Channel	
Bottom Width	2.000	m
Channel Slope	0.0531	m/m
Manning's n (channel)	0.035	
Channel Invert Elevation	371.730	m
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	m
Crest Length	2.000	m
Crest Elevation	374.000	m
Roadway Surface	Gravel	
Top Width	6.000	m

Culvert Properties

Culvert 1

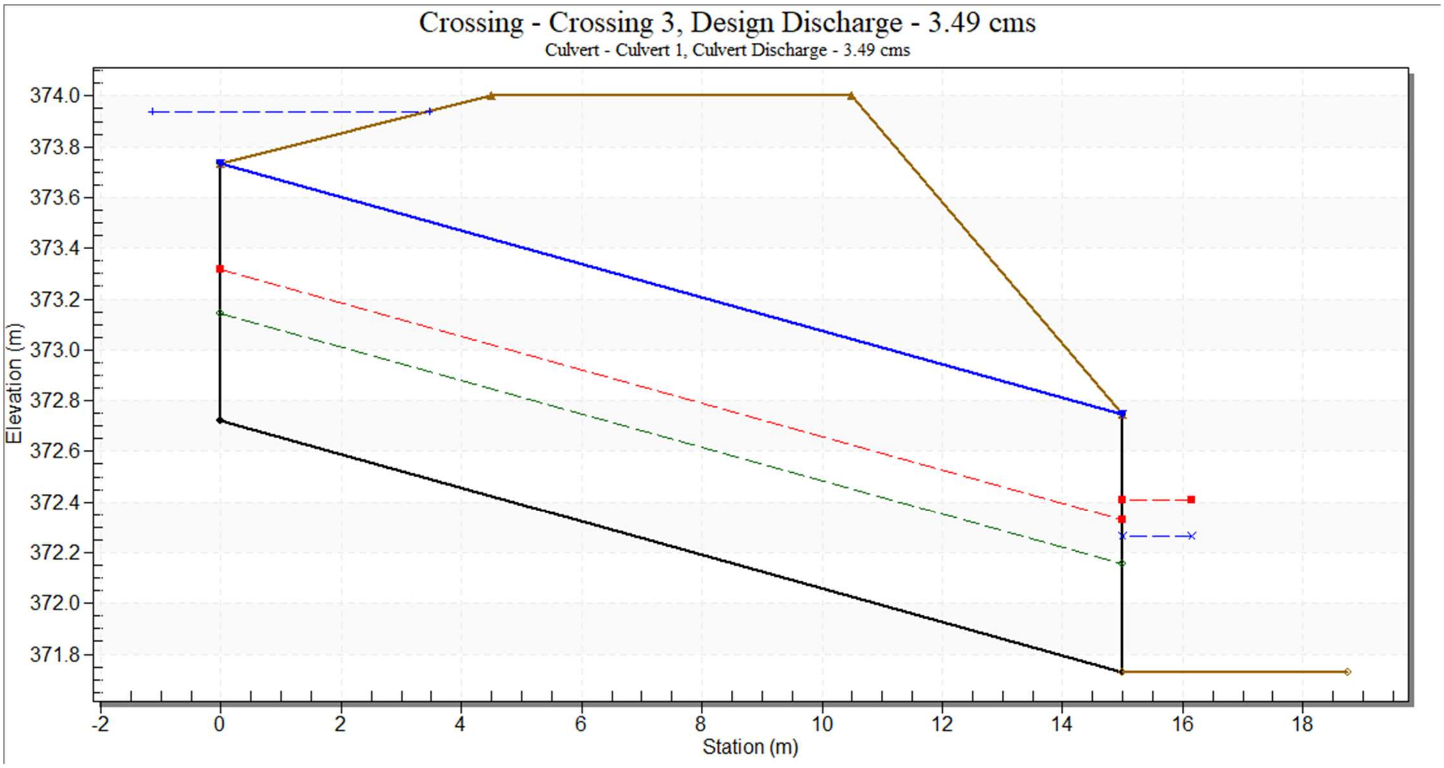
Add Culvert

Duplicate Culvert

Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Arch, Open Bottom	
Material	Corrugated Steel	
Size	Define...	
Span	2.438	m
Rise	1.016	m
Embedment Depth	0.000	mm
Manning's n (Top/Sides)	0.020	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting (Ke=0.9)	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	m
Inlet Elevation	372.720	m
Outlet Station	15.000	m
Outlet Elevation	371.730	m

Watercourse Crossing 3 Design Discharge



Watercourse Crossing 3 Summary Table

Headwater Elevation (m)	Total Discharge (cms)	Culvert 1 Discharge (cms)	Roadway Discharge (cms)	Iterations
373.79	3.01	3.01	0.00	1
373.81	3.07	3.07	0.00	1
373.83	3.13	3.13	0.00	1
373.85	3.19	3.19	0.00	1
373.86	3.25	3.25	0.00	1
373.88	3.30	3.30	0.00	1
373.90	3.36	3.36	0.00	1
373.92	3.42	3.42	0.00	1
373.94	3.49	3.49	0.00	1
373.95	3.54	3.54	0.00	1
373.97	3.60	3.60	0.00	1
374.00	3.69	3.69	0.00	Overtopping

Appendix C Drawings

NOTE:

1. ALL DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION FOR HIGHWAY WORKS AND THE TURBINE MANUFACTURERS STANDARDS AND ALL RELEVANT DRAWINGS WITHIN THE PROJECT DESIGN PACKAGE.
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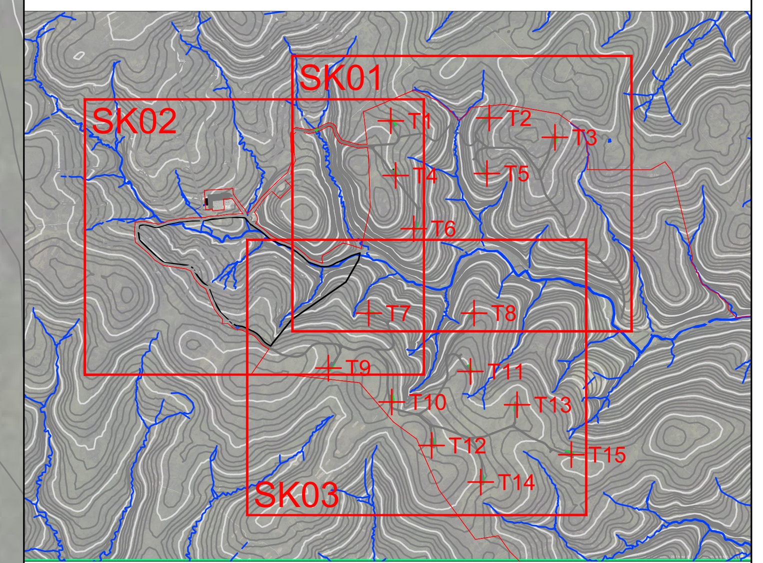
6. ALL WORKS ARE TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENT OF THE STATUTORY AUTHORITIES AND CONSTRUCTION DESIGN MANAGEMENT REGULATIONS.

KEY PLAN:



KEY:

- SITE BOUNDARY
- EXISTING WATERCOURSE
- EXISTING 5m CONTOUR
- T12 PROPOSED TURBINE
- PROPOSED WATERCOURSE CROSSING
- EXISTING WATERCOURSE CROSSING TO BE UPGRADED
- PROPOSED ACCESS TRACK
- EXISTING ACCESS TRACK
- PROPOSED HARDSTANDING (PERMANENT)
- PROPOSED SUBSTATION EXTENSION (PERMANENT)
- PROPOSED TRACKSIDE DRAINAGE
- INDICATIVE SETTLEMENT/ DISPERSAL BASIN

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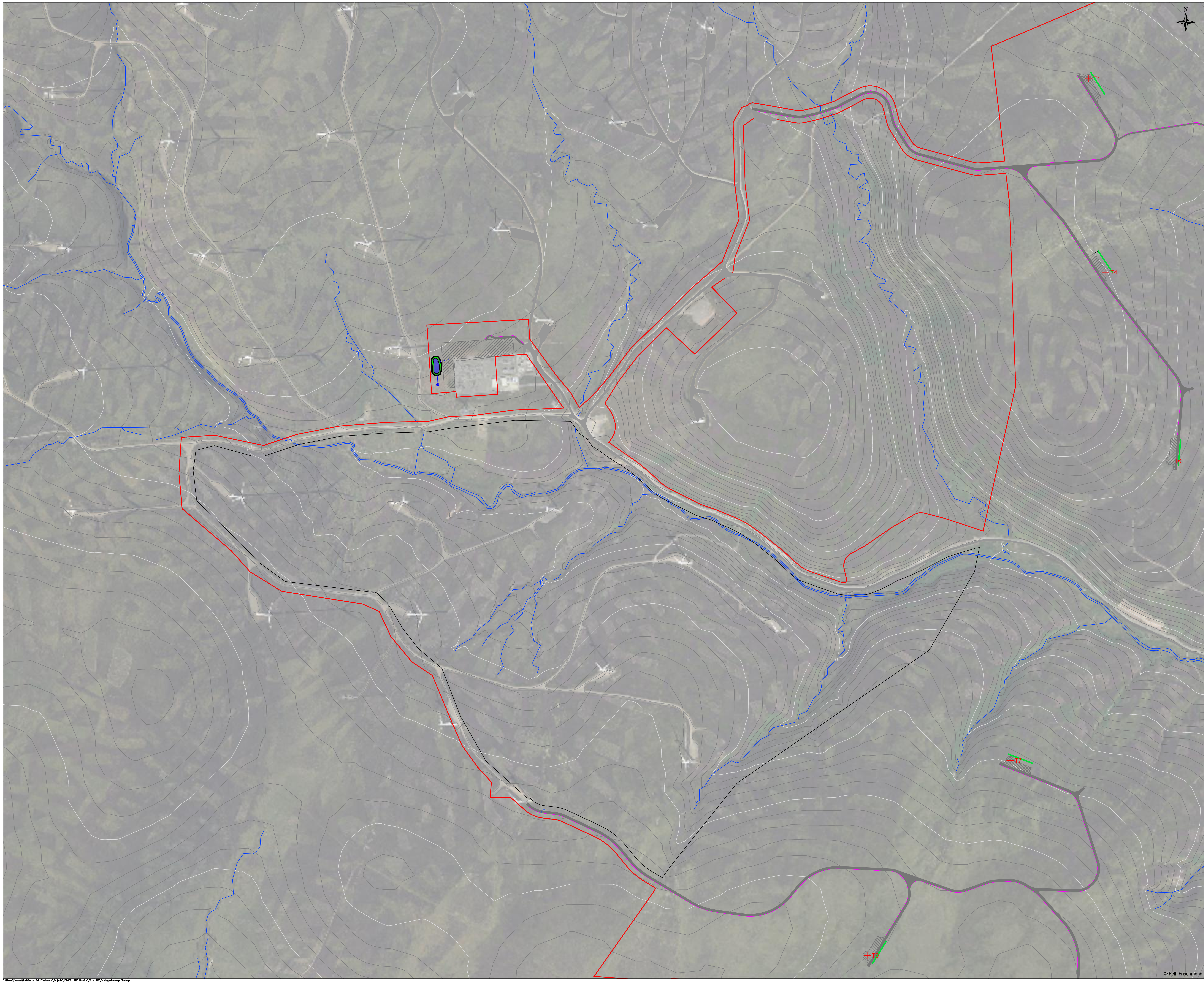
Client
LUC

Project
DUNSIDE WIND FARM

Drawing Title
DRAINAGE STRATEGY
SHEET 1 OF 3

	Name	Date	
			Scale 1:5000 @ A1
Designed	RL	19.05.2023	File 230519_DrainageStrategy
Checked	KI	19.05.2023	Drawing Status DRAFT

Drawing No. SK01 | Revision P1



NOTE:

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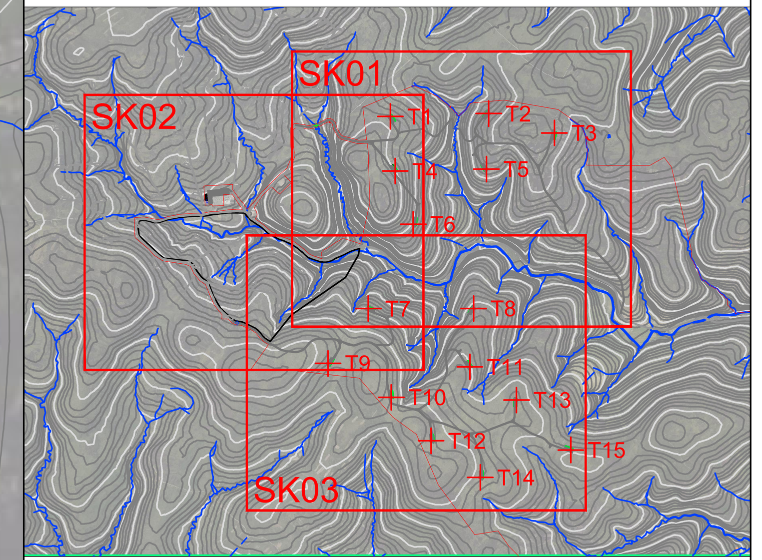
KEY PLAN:



KEY:

- SITE BOUNDARY
- EXISTING WATERCOURSE
- EXISTING 5m CONTOUR
- T12 PROPOSED TURBINE
- PROPOSED WATERCOURSE CROSSING
- EXISTING WATERCOURSE CROSSING TO BE UPGRADED
- PROPOSED ACCESS TRACK
- EXISTING ACCESS TRACK
- PROPOSED HARDSTANDING (PERMANENT)
- PROPOSED SUBSTATION EXTENSION (PERMANENT)
- PROPOSED TRACKSIDE DRAINAGE
- INDICATIVE SETTLEMENT/ DISPERSAL BASIN

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Client: LUC

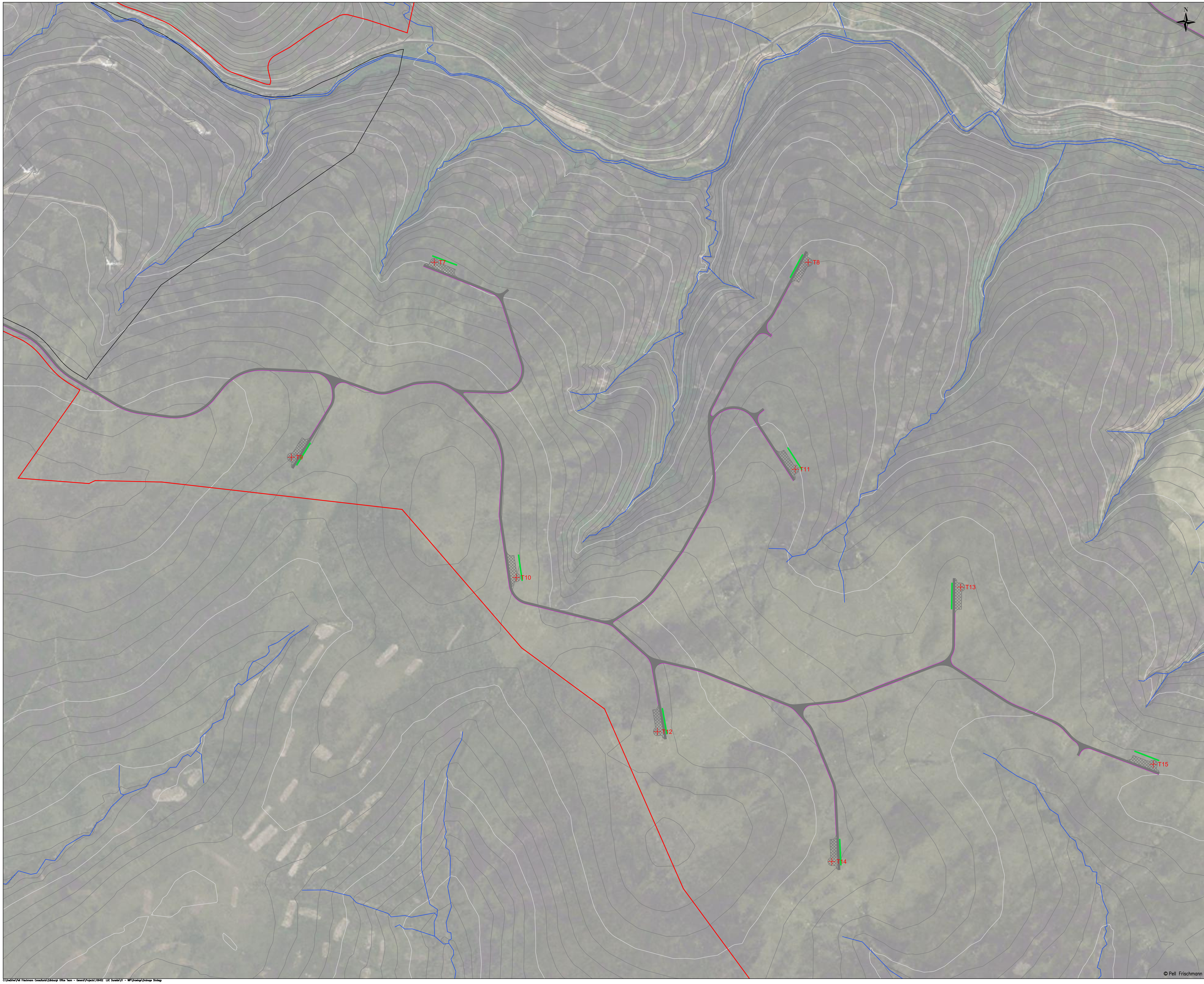
Project: DUNSIDE WIND FARM

Drawing Title: DRAINAGE STRATEGY SHEET 2 OF 3

	Name	Date	
Designed	RL	15.05.2023	Scale: 1:5000 @ A1
Checked	KI	13.06.2023	File: 230519_DrainageStrategy
			Drawing Status: DRAFT

Drawing No.: SK02

Revision: P1



NOTE:

1. ALL DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION FOR HIGHWAY WORKS AND THE TURBINE MANUFACTURERS STANDARDS AND ALL RELEVANT DRAWINGS WITHIN THE PROJECT DESIGN PACKAGE.
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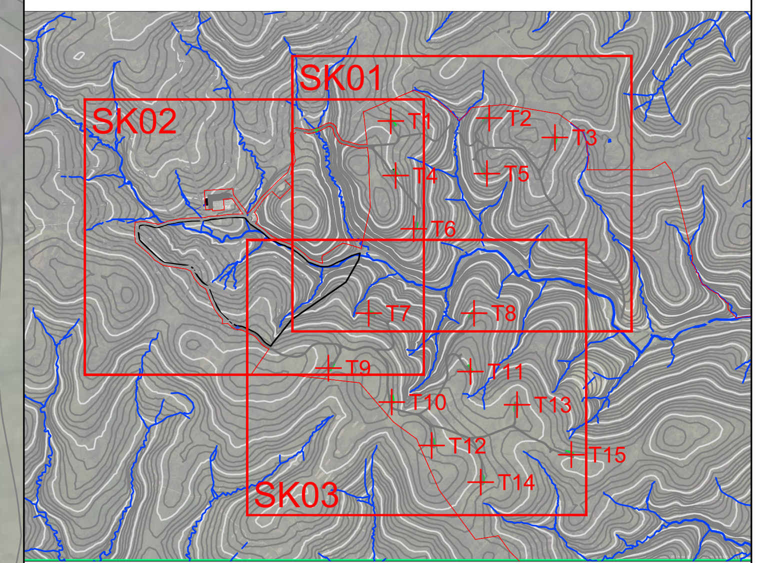
KEY PLAN:



KEY:

- SITE BOUNDARY
- EXISTING WATERCOURSE
- EXISTING 5m CONTOUR
- T12 PROPOSED TURBINE
- PROPOSED WATERCOURSE CROSSING
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- EXISTING ACCESS TRACK
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- PROPOSED SUBSTATION EXTENSION (PERMANENT)
- PROPOSED TRACKSIDE DRAINAGE
- INDICATIVE SETTLEMENT/ DISPERSAL BASIN

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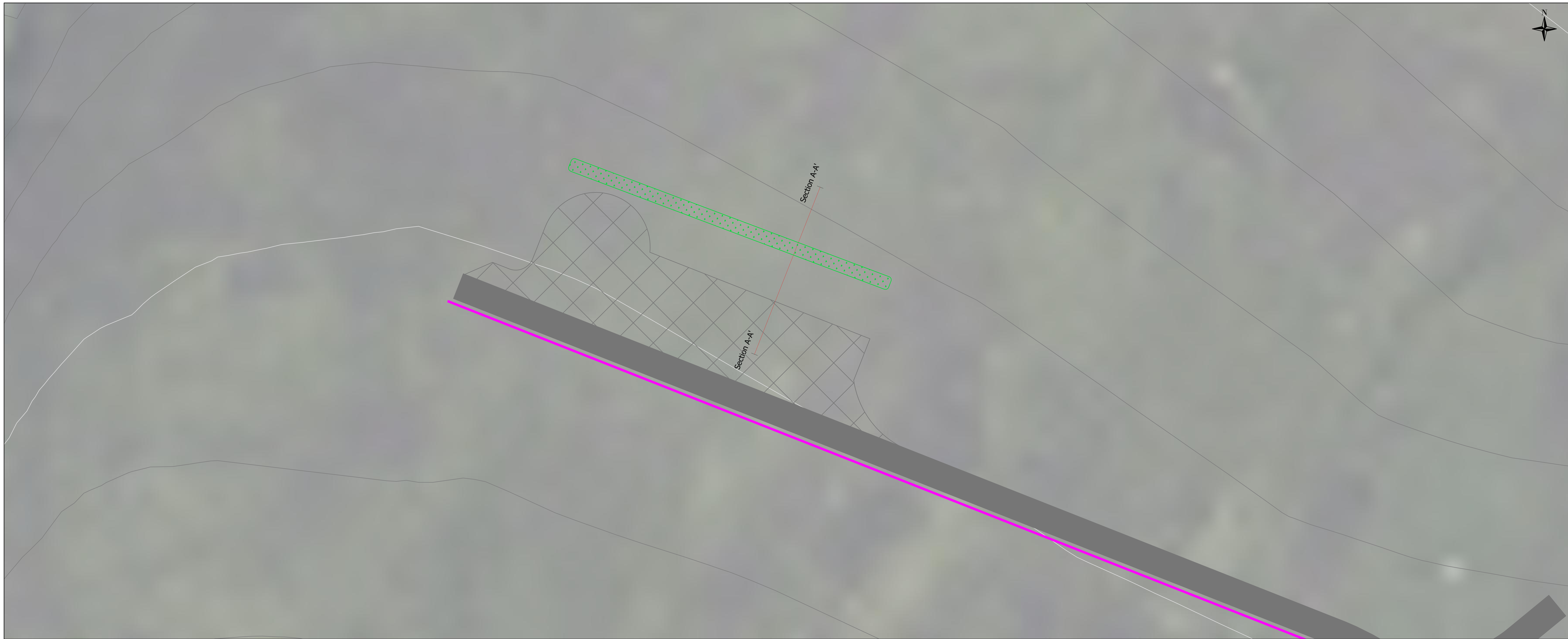
Client: LUC

Project: DUNSIDE WIND FARM

Drawing Title: DRAINAGE STRATEGY SHEET 3 OF 3

	Name	Date		
			Scale	1:5000 @ A1
Designed	RL	19.05.2023	File	230519_DrainageStrategy
Checked	KI	19.05.2023	Drawing Status	DRAFT
Drawing No.	SK03		Revision	P1



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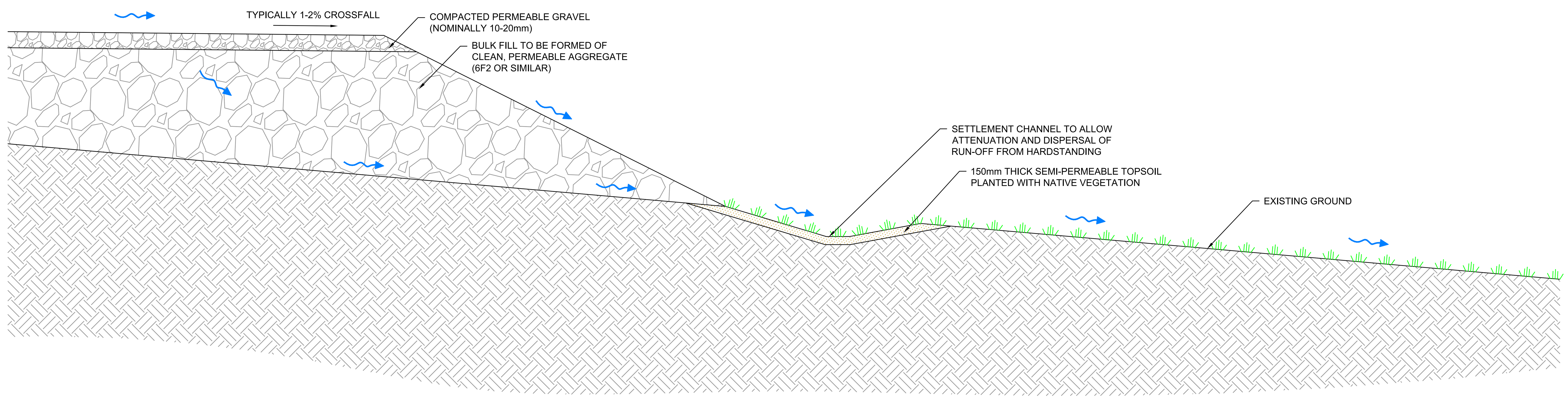
KEY:

- EXISTING 5m CONTOUR
- PROPOSED ACCESS TRACK
- PROPOSED HARDSTANDING (PERMANENT)
- PROPOSED TRACKSIDE DRAINAGE
- INDICATIVE SETTLEMENT/ DISPERSAL BASIN



SECTION A-A'

1:50

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Client

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Project

DUNSIDE WIND FARM

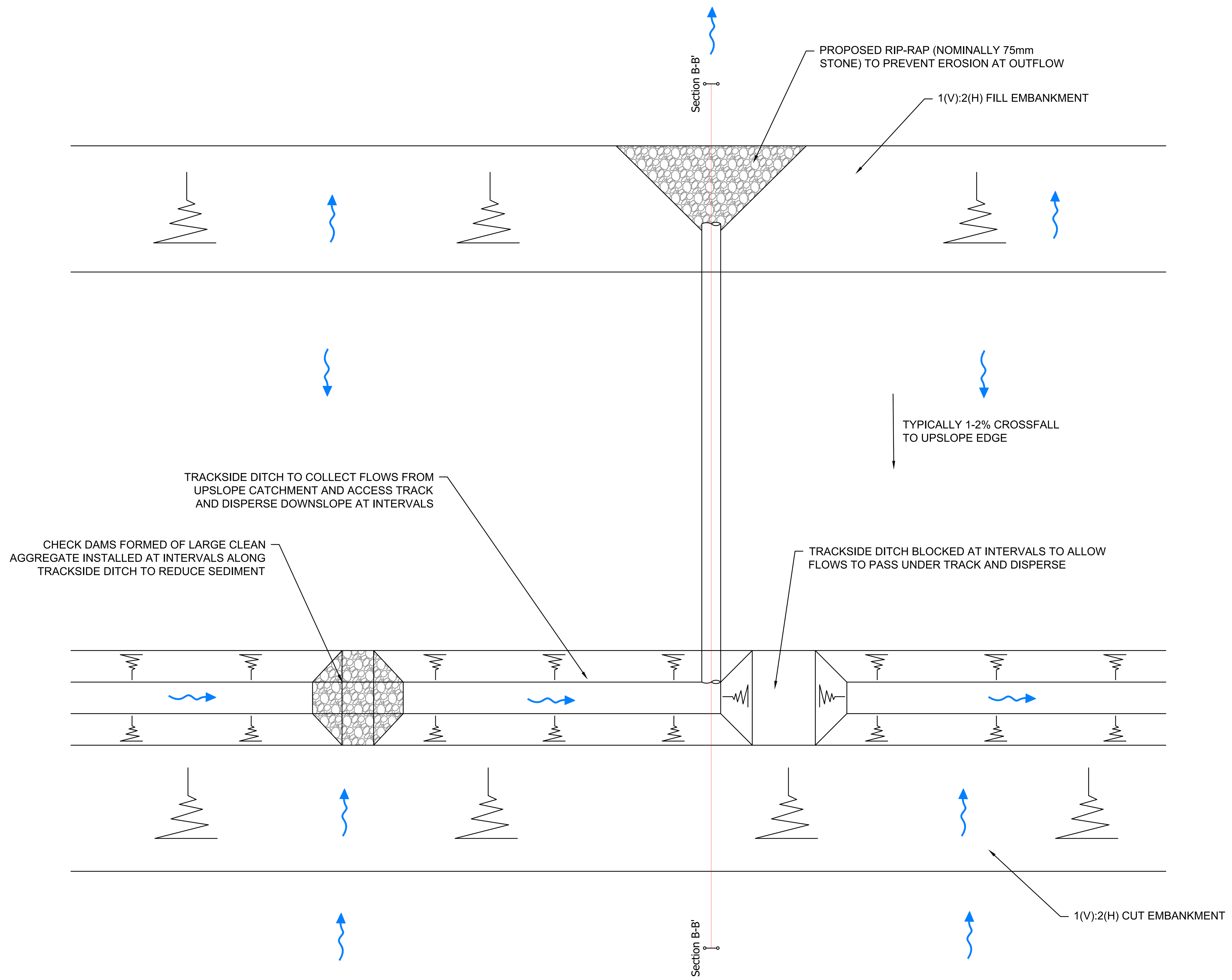
Drawing Title

INDICATIVE HARDSTAND DRAINAGE ARRANGEMENT

	Name	Date	
			Scale 1:500 @ A1
Designed	RL	19.05.2023	File 230519_DrainageStrategy
Checked	KI	19.05.2023	Drawing Status DRAFT

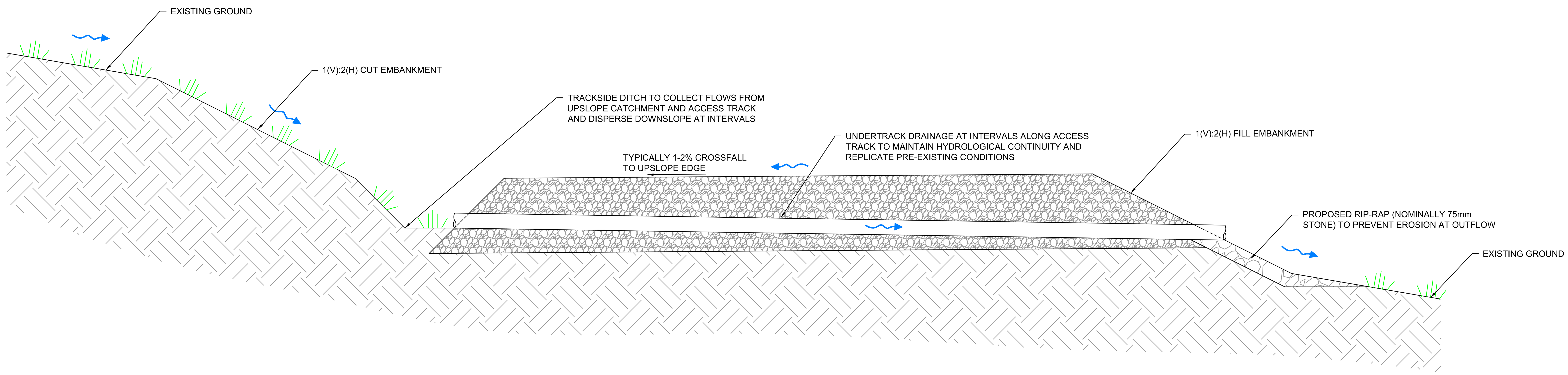
Drawing No. SK04

Revision P1



INDICATIVE TRACKSIDE DRAINAGE ARRANGEMENT - PLAN VIEW

1:50



SECTION B-B'

1:25

NOTE:

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DUNSIDE WIND FARM

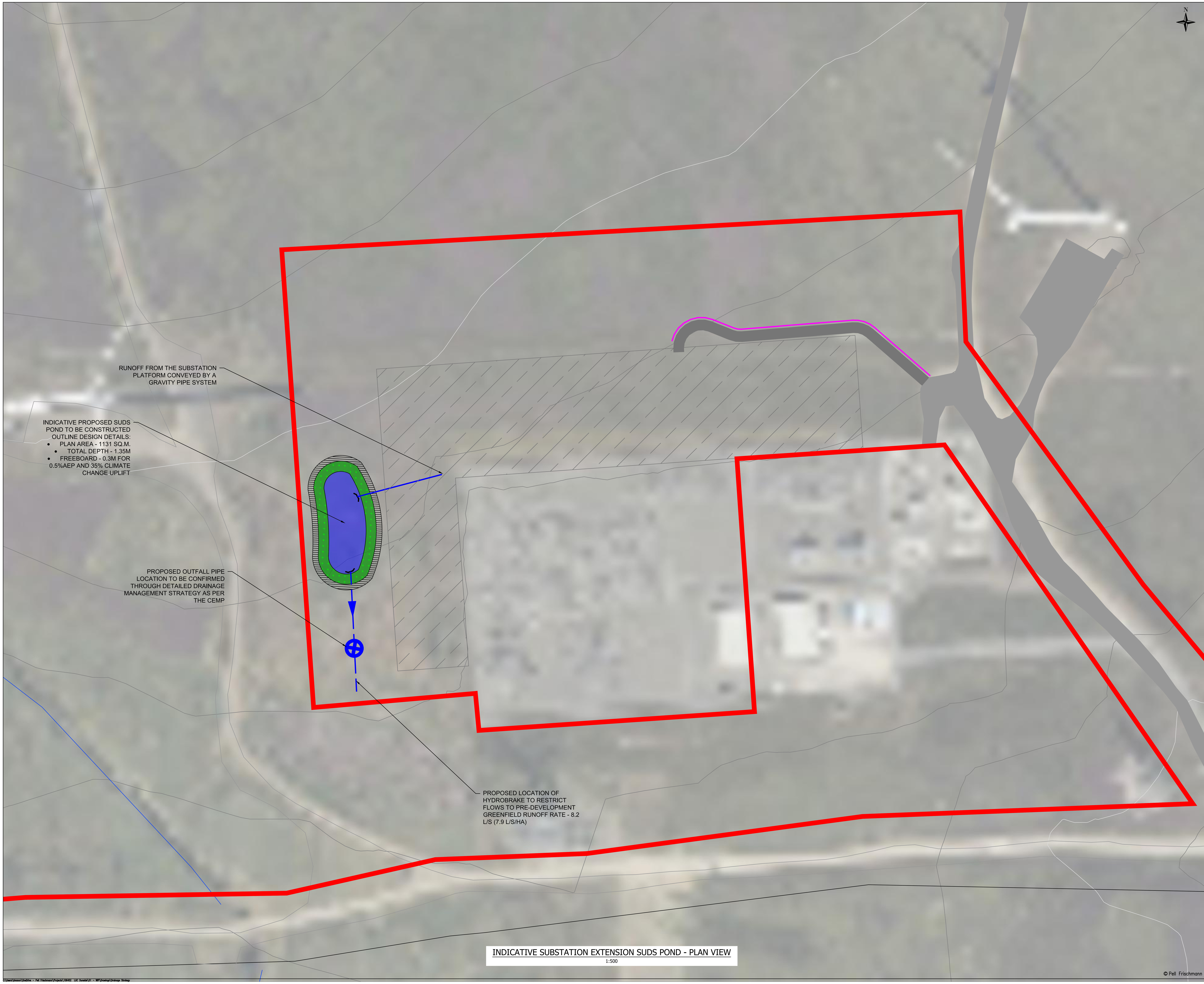
Drawing Title

INDICATIVE TRACKSIDE DRAINAGE ARRANGEMENT

	Name	Date		
			Scale	1:50 @ A1
Designed	RL	19.05.2023	File	230519_DrainageStrategy
Checked	KI	19.05.2023	Drawing Status	DRAFT

Drawing No. SK05

Revision P1



INDICATIVE SUBSTATION EXTENSION SUDS POND - PLAN VIEW

1:500

NOTE:

1. ALL DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION FOR HIGHWAY WORKS AND THE TURBINE MANUFACTURERS STANDARDS AND ALL RELEVANT DRAWINGS WITHIN THE PROJECT DESIGN PACKAGE.
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KEY:

- PROPOSED ACCESS TRACK
- EXISTING ACCESS TRACK
- PROPOSED SUBSTATION EXTENSION (PERMANENT)
- PROPOSED TRACKSIDE DRAINAGE
- INDICATIVE SUDS POND
- PROPOSED HYDRO-BRAKE

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Project

DUNSIDE WIND FARM

Drawing Title

INDICATIVE SUBSTATION EXTENSION DRAINAGE ARRANGEMENT

	Name	Date
Designed	RL	15.05.2023
Checked	KI	07.06.2023

Scale: 1:750 @ A1

File: 230519_DrainageStrategy

Drawing Status: DRAFT

Drawing No.: SK06

Revision: P1

Appendix D MicroDrainage Attenuation

Summary of Results for 200 year Return Period (+35%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	0.331	0.331	8.2	247.5	O K
30 min Summer	0.452	0.452	8.2	346.3	O K
60 min Summer	0.574	0.574	8.2	450.2	O K
120 min Summer	0.696	0.696	8.2	558.8	O K
180 min Summer	0.765	0.765	8.2	621.7	O K
240 min Summer	0.810	0.810	8.2	664.2	O K
360 min Summer	0.866	0.866	8.2	717.5	O K
480 min Summer	0.897	0.897	8.2	747.7	O K
600 min Summer	0.914	0.914	8.2	764.6	O K
720 min Summer	0.922	0.922	8.2	772.9	O K
960 min Summer	0.930	0.930	8.2	779.8	O K
1440 min Summer	0.929	0.929	8.2	779.3	O K
2160 min Summer	0.912	0.912	8.2	762.1	O K
2880 min Summer	0.884	0.884	8.2	735.6	O K
4320 min Summer	0.819	0.819	8.2	673.0	O K
5760 min Summer	0.747	0.747	8.2	605.4	O K
7200 min Summer	0.665	0.665	8.2	530.7	O K
8640 min Summer	0.569	0.569	8.2	445.4	O K
10080 min Summer	0.489	0.489	8.2	377.0	O K
15 min Winter	0.369	0.369	8.2	277.7	O K
30 min Winter	0.503	0.503	8.2	389.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	103.865	0.0	242.2	19
30 min Summer	73.226	0.0	343.4	34
60 min Summer	48.326	0.0	465.3	64
120 min Summer	30.750	0.0	592.7	122
180 min Summer	23.380	0.0	676.0	182
240 min Summer	19.202	0.0	740.1	242
360 min Summer	14.502	0.0	837.9	362
480 min Summer	11.865	0.0	913.0	480
600 min Summer	10.147	0.0	974.6	600
720 min Summer	8.926	0.0	1026.9	714
960 min Summer	7.289	0.0	1111.5	820
1440 min Summer	5.476	0.0	1197.8	1082
2160 min Summer	4.112	0.0	1438.1	1492
2880 min Summer	3.351	0.0	1561.6	1904
4320 min Summer	2.507	0.0	1747.7	2764
5760 min Summer	2.038	0.0	1905.6	3576
7200 min Summer	1.735	0.0	2027.6	4392
8640 min Summer	1.521	0.0	2132.2	5096
10080 min Summer	1.361	0.0	2222.9	5752
15 min Winter	103.865	0.0	271.9	19
30 min Winter	73.226	0.0	384.8	33

Summary of Results for 200 year Return Period (+35%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	0.638	0.638	8.2	506.7	O K
120 min Winter	0.773	0.773	8.2	629.7	O K
180 min Winter	0.849	0.849	8.2	701.6	O K
240 min Winter	0.900	0.900	8.2	751.2	O K
360 min Winter	0.965	0.965	8.2	815.4	O K
480 min Winter	1.004	1.004	8.2	854.0	O K
600 min Winter	1.027	1.027	8.3	877.8	O K
720 min Winter	1.041	1.041	8.3	892.1	O K
960 min Winter	1.052	1.052	8.4	902.8	O K
1440 min Winter	1.046	1.046	8.4	897.1	O K
2160 min Winter	1.019	1.019	8.3	869.0	O K
2880 min Winter	0.975	0.975	8.2	824.6	O K
4320 min Winter	0.870	0.870	8.2	721.3	O K
5760 min Winter	0.753	0.753	8.2	610.9	O K
7200 min Winter	0.601	0.601	8.2	473.2	O K
8640 min Winter	0.462	0.462	8.2	354.0	O K
10080 min Winter	0.349	0.349	8.2	262.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	48.326	0.0	521.4	62
120 min Winter	30.750	0.0	663.9	122
180 min Winter	23.380	0.0	757.0	180
240 min Winter	19.202	0.0	828.6	238
360 min Winter	14.502	0.0	937.5	354
480 min Winter	11.865	0.0	1020.7	468
600 min Winter	10.147	0.0	1088.3	582
720 min Winter	8.926	0.0	1144.5	692
960 min Winter	7.289	0.0	1227.6	904
1440 min Winter	5.476	0.0	1233.7	1138
2160 min Winter	4.112	0.0	1610.6	1604
2880 min Winter	3.351	0.0	1748.8	2072
4320 min Winter	2.507	0.0	1954.7	2980
5760 min Winter	2.038	0.0	2134.5	3864
7200 min Winter	1.735	0.0	2271.3	4616
8640 min Winter	1.521	0.0	2388.7	5272
10080 min Winter	1.361	0.0	2491.0	5944

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	200	Cv (Summer)	0.750
Region	Scotland and Ireland	Cv (Winter)	0.840
M5-60 (mm)	15.600	Shortest Storm (mins)	15
Ratio R	0.258	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+35

Time Area Diagram

Total Area (ha) 1.300

Time From:	**(mins) To:**	**Area (ha)**
0	4	1.300

Model Details

Storage is Online Cover Level (m) 1.352

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	700.0	0.500	847.8	1.000	1009.6	1.350	1131.4

Hydro-Brake® Optimum Outflow Control

Unit Reference	MD-SHE-0133-8200-1000-8200
Design Head (m)	1.000
Design Flow (l/s)	8.2
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	133
Invert Level (m)	0.000
Minimum Outlet Pipe Diameter (mm)	150
Suggested Manhole Diameter (mm)	1200

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	1.000	8.2
Flush-Flo™	0.301	8.2
Kick-Flo®	0.662	6.8
Mean Flow over Head Range	-	7.0

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	4.8	1.200	8.9	3.000	13.8	7.000	20.6
0.200	7.9	1.400	9.6	3.500	14.8	7.500	21.3
0.300	8.2	1.600	10.2	4.000	15.8	8.000	22.0
0.400	8.1	1.800	10.8	4.500	16.7	8.500	22.7
0.500	7.8	2.000	11.4	5.000	17.6	9.000	23.3
0.600	7.4	2.200	11.9	5.500	18.4	9.500	23.9
0.800	7.4	2.400	12.4	6.000	19.2		
1.000	8.2	2.600	12.9	6.500	19.9		

Summary of Results for 200 year Return Period (+35%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	0.376	0.376	1.4	45.7	O K
30 min Summer	0.497	0.497	1.4	63.9	O K
60 min Summer	0.611	0.611	1.4	83.1	O K
120 min Summer	0.718	0.718	1.4	102.7	O K
180 min Summer	0.776	0.776	1.4	113.9	O K
240 min Summer	0.813	0.813	1.4	121.6	O K
360 min Summer	0.859	0.859	1.4	131.1	O K
480 min Summer	0.884	0.884	1.4	136.4	O K
600 min Summer	0.897	0.897	1.4	139.4	O K
720 min Summer	0.904	0.904	1.4	140.7	Flood Risk
960 min Summer	0.908	0.908	1.4	141.6	Flood Risk
1440 min Summer	0.905	0.905	1.4	141.0	Flood Risk
2160 min Summer	0.891	0.891	1.4	137.9	O K
2880 min Summer	0.871	0.871	1.4	133.6	O K
4320 min Summer	0.822	0.822	1.4	123.4	O K
5760 min Summer	0.769	0.769	1.4	112.6	O K
7200 min Summer	0.714	0.714	1.4	101.9	O K
8640 min Summer	0.658	0.658	1.4	91.5	O K
10080 min Summer	0.600	0.600	1.4	81.2	O K
15 min Winter	0.415	0.415	1.4	51.3	O K
30 min Winter	0.545	0.545	1.4	71.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	103.865	0.0	46.3	19
30 min Summer	73.226	0.0	65.3	34
60 min Summer	48.326	0.0	86.8	64
120 min Summer	30.750	0.0	110.4	122
180 min Summer	23.380	0.0	125.9	182
240 min Summer	19.202	0.0	137.9	242
360 min Summer	14.502	0.0	156.2	362
480 min Summer	11.865	0.0	170.3	482
600 min Summer	10.147	0.0	181.9	600
720 min Summer	8.926	0.0	191.9	718
960 min Summer	7.289	0.0	207.9	828
1440 min Summer	5.476	0.0	213.1	1084
2160 min Summer	4.112	0.0	266.3	1496
2880 min Summer	3.351	0.0	289.3	1928
4320 min Summer	2.507	0.0	324.3	2764
5760 min Summer	2.038	0.0	352.1	3576
7200 min Summer	1.735	0.0	374.7	4392
8640 min Summer	1.521	0.0	394.2	5184
10080 min Summer	1.361	0.0	411.4	5952
15 min Winter	103.865	0.0	51.9	19
30 min Winter	73.226	0.0	73.1	33

Summary of Results for 200 year Return Period (+35%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	0.669	0.669	1.4	93.5	O K
120 min Winter	0.785	0.785	1.4	115.9	O K
180 min Winter	0.849	0.849	1.4	129.0	O K
240 min Winter	0.891	0.891	1.4	138.1	O K
360 min Winter	0.944	0.944	1.5	149.8	Flood Risk
480 min Winter	0.975	0.975	1.5	156.8	Flood Risk
600 min Winter	0.994	0.994	1.5	161.2	Flood Risk
720 min Winter	1.005	1.005	1.5	163.8	Flood Risk
960 min Winter	1.013	1.013	1.5	165.8	Flood Risk
1440 min Winter	1.007	1.007	1.5	164.3	Flood Risk
2160 min Winter	0.986	0.986	1.5	159.4	Flood Risk
2880 min Winter	0.954	0.954	1.5	152.0	Flood Risk
4320 min Winter	0.877	0.877	1.4	135.0	O K
5760 min Winter	0.793	0.793	1.4	117.4	O K
7200 min Winter	0.706	0.706	1.4	100.4	O K
8640 min Winter	0.613	0.613	1.4	83.5	O K
10080 min Winter	0.482	0.482	1.4	61.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	48.326	0.0	97.2	62
120 min Winter	30.750	0.0	123.7	122
180 min Winter	23.380	0.0	141.0	180
240 min Winter	19.202	0.0	154.4	238
360 min Winter	14.502	0.0	174.8	354
480 min Winter	11.865	0.0	190.5	468
600 min Winter	10.147	0.0	203.3	582
720 min Winter	8.926	0.0	213.8	692
960 min Winter	7.289	0.0	222.5	906
1440 min Winter	5.476	0.0	218.7	1142
2160 min Winter	4.112	0.0	298.2	1620
2880 min Winter	3.351	0.0	323.9	2076
4320 min Winter	2.507	0.0	362.9	2980
5760 min Winter	2.038	0.0	394.4	3856
7200 min Winter	1.735	0.0	419.7	4688
8640 min Winter	1.521	0.0	441.6	5536
10080 min Winter	1.361	0.0	460.8	6352

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	200	Cv (Summer)	0.750
Region	Scotland and Ireland	Cv (Winter)	0.840
M5-60 (mm)	15.600	Shortest Storm (mins)	15
Ratio R	0.258	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+35

Time Area Diagram

Total Area (ha) 0.240

Time From:	**(mins) To:**	**Area (ha)**
0	4	0.240

Model Details

Storage is Online Cover Level (m) 1.200

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	100.0	0.500	160.2	1.000	234.6	1.200	268.3

Hydro-Brake® Optimum Outflow Control

Unit Reference	MD-SHE-0058-1500-1000-1500
Design Head (m)	1.000
Design Flow (l/s)	1.5
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	58
Invert Level (m)	0.000
Minimum Outlet Pipe Diameter (mm)	75
Suggested Manhole Diameter (mm)	1200

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	1.000	1.5
Flush-Flo™	0.253	1.4
Kick-Flo®	0.515	1.1
Mean Flow over Head Range	-	1.2

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	1.2	1.200	1.6	3.000	2.5	7.000	3.7
0.200	1.4	1.400	1.7	3.500	2.7	7.500	3.8
0.300	1.4	1.600	1.9	4.000	2.8	8.000	3.9
0.400	1.3	1.800	2.0	4.500	3.0	8.500	4.0
0.500	1.2	2.000	2.0	5.000	3.1	9.000	4.1
0.600	1.2	2.200	2.1	5.500	3.3	9.500	4.2
0.800	1.4	2.400	2.2	6.000	3.4		
1.000	1.5	2.600	2.3	6.500	3.5		