Appendix 8-2

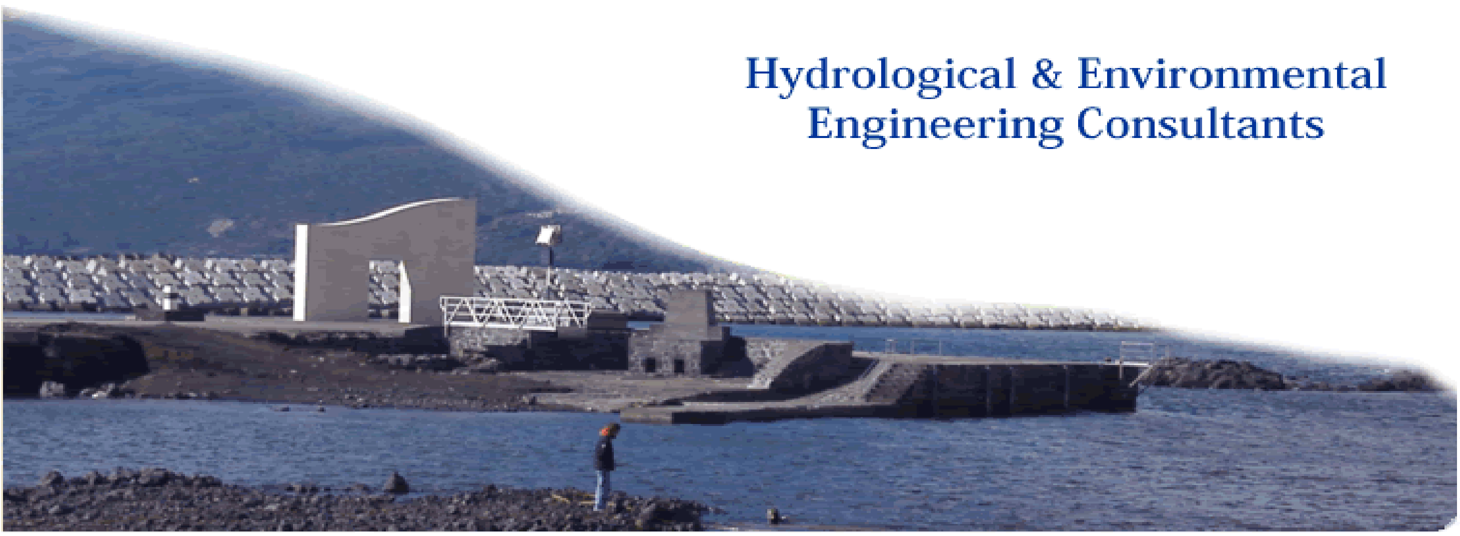
Flood Risk Assessment Report

Flood Risk Assessment of a proposed Solar Farm Development at Timahoe North Co. Kildare.

On behalf of

ESBI

July 2018



Flood Risk Assessment of a proposed Solar Farm Development at Timahoe North Co. Kildare.

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1. Introduction

1.1 Background

The project site is located in the townland of Timahoe, to the north of the Timahoe crossroads and 7 km south of Johnstown Bridge Co Kildare, refer to Figure 1. The subject lands are referred to as the Timahoe North Bog. This land is a cutaway raised bog that forms part of Bord Na Mona (BNM) commercial bog at Timahoe. This bog went in to production by BNM in the 1950’s and ceased production approximately 25years ago (in the early 1990’s). The area of this cutaway bog is large at almost 8 km² (800 ha) in area. The topography of the bog is saucer like with lands slightly elevated to the southwest and northeast and a large flat section in the middle generally at elevations below 80 m OD.

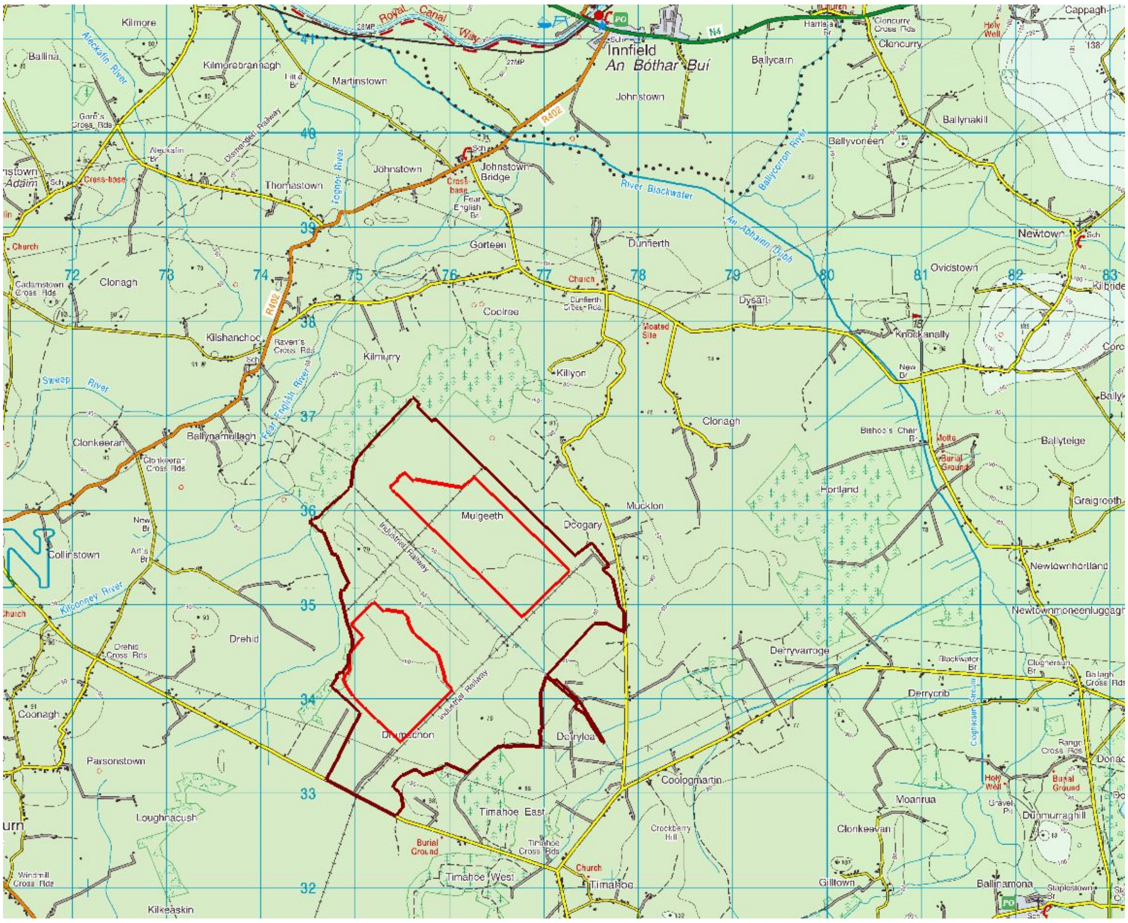

Figure 1 Timahoe North Bog Study Area

The bog has large wide man-made drains running in a north-west - south-east longitudinal direction, spaced c. 250m apart and totalling 11 main (continuous) longitudinal drains across the full width of the site. There are a number of other, similarly orientated, drains that are discontinued with standing water only. Two raised disused rail line tracks running transversely across the bog from the southwest to northeast are present which facilitated a narrow gauge rail line to the site during peat production.

The bog is bounded to the northwest and north by a tributary of the Fear English River which flows northwards away from the site and joins the Kells Blackwater (Boyne River System). To the south the bog is bounded by open drains that form the Mulgeeth tributary which flows southeast away from the site past Doran Nurseries before heading northeast and north to eventually join the Kells Blackwater.

2. Proposed Solar Farm Development

2.1 Description

The proposed Solar Farm is to be confined to two large areas located on the east and west sides of the cutaway bog and north of the first disused rail line track. The areas involved are 100 ha and 119 ha for the western area (Site 1) and eastern area (Site 2) respectively. The western area includes the substation, 12 inverters, 85 ha of solar panel arrays, 4 peat repository areas totalling 8.2 ha, compound area and access tracks to the Inverters and solar array and longitudinal drains and drainage network. The Eastern area includes 17 inverters, 117 ha of solar panel arrays, access tracks, longitudinal drains and drainage network and a number of small peat repository areas. See figure 2.

The two solar development sites (NE and SW sites) within the BNM Timahoe North Bog have been selected on generally higher drier ground so as to avoid the lower-lying flood prone areas of the bog which are associated with the central section of the bog, refer to Figure 3.

To avoid any potential flood risk the solar panels, proposed access tracks and inverters which are in potential flood prone areas to be raised above the predicted 1000 year flood level. The peat repository areas, substation and the compound area are to be located on more elevated land above the predicted 1000 year flood level.

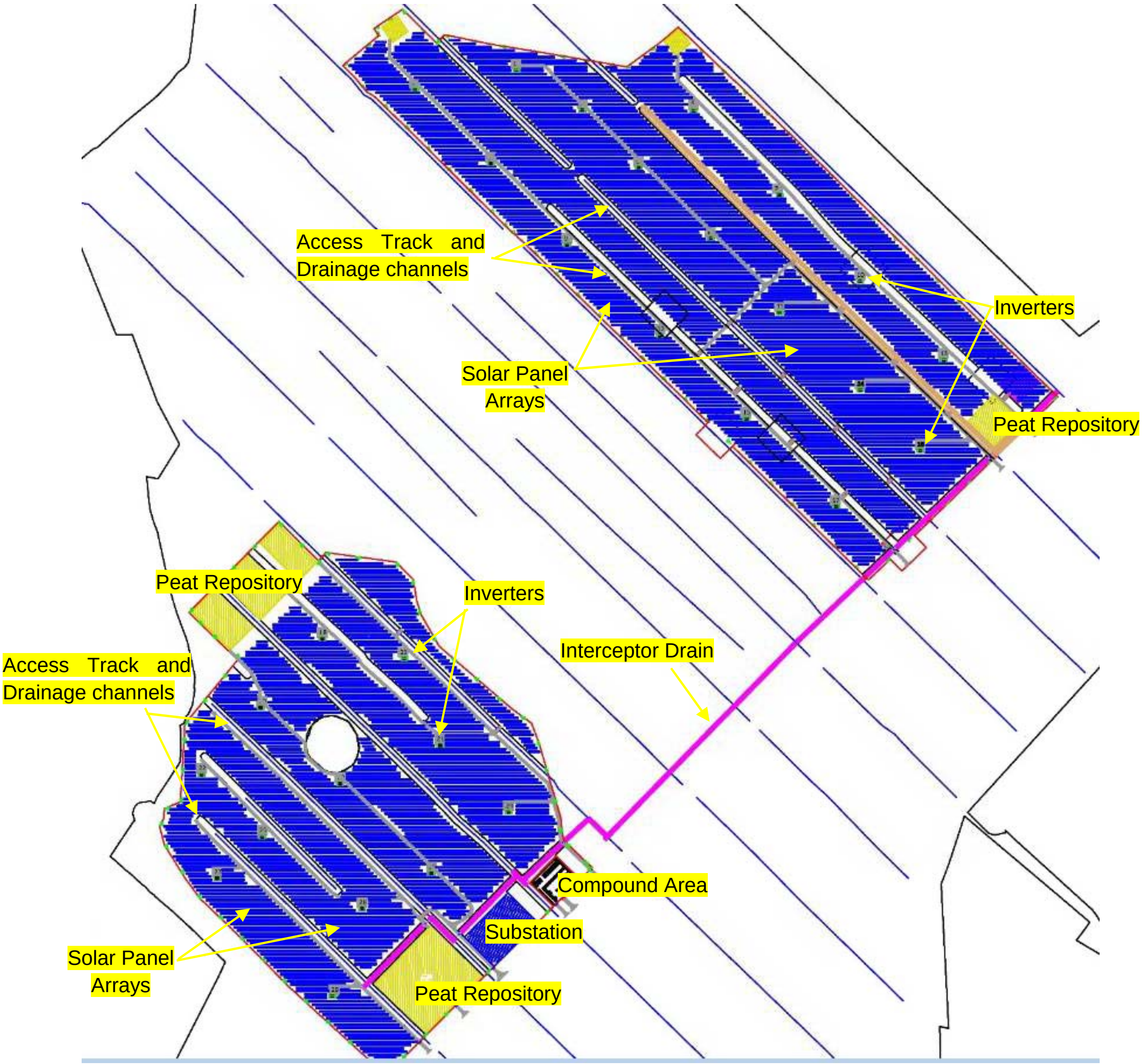

Figure 2 Proposed Layout of Solar Farm at Timahoe North

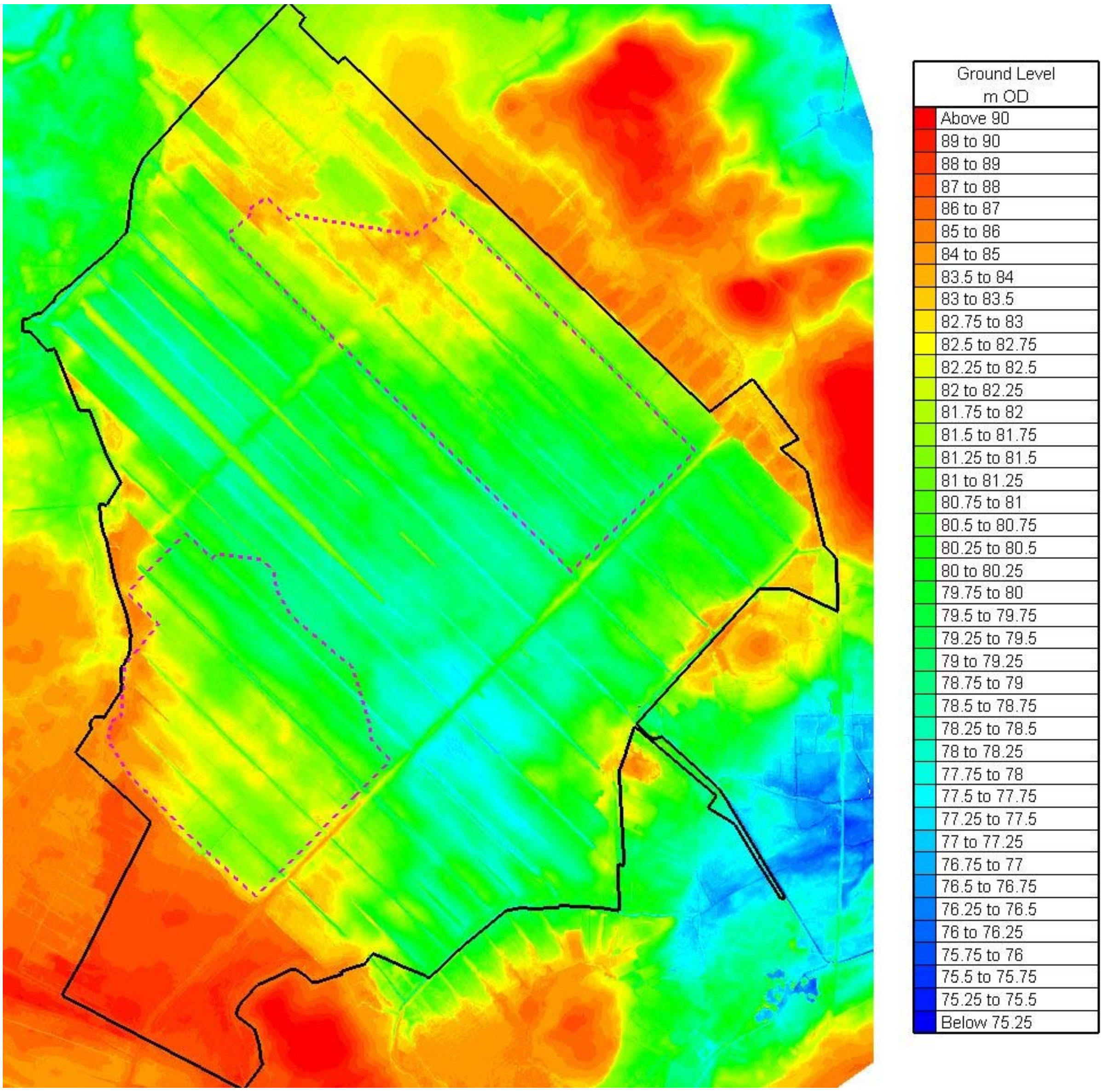

Figure 3 Tonal Plot of Lidar data for Timahoe North Site showing low-lying flood prone lands in cyan and blue and elevated ground in yellow, orange and reds

Note: *The solar development sites shown as a broken magenta outlines above generally avoid the lower-lying (cyan) areas of the site and occupy the drier section of the bog*

3. Planning Guidelines Concerning Flood Risk Management

3.1 Background

In November 2009, the OPW and DoEHLG jointly published for public consultation Flood risk management planning guidelines entitled "The Planning System and Flood Risk Management" which is aimed at ensuring a more consistent, rigorous and systematic approach to fully incorporate flood risk assessment and management into the planning system, both at the strategic level of county/city and local area plans and at the specific level of planning application assessments. The aim of these planning guidelines is a tiered system of avoidance of flood risk where possible, substitution with less vulnerable development where avoidance is not possible, Justification of development where avoidance and substitution are not possible and mitigate and manage to reduce flood risk and damage to acceptable levels where justification test permits the development.

The flood risk management planning guidelines sets out how to assess and manage flood risk potential and includes guidance on the preparation of flood risk assessments by developers.

The recommended stages of assessment are:

Screening Assessment – to identify whether there may be flooding or surface water management issues related to a plan area or proposed development site that may warrant further investigation;

Scoping assessment to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information and to scope the extent of the risk of flooding and potential impact of a development on flooding elsewhere and of the scope of possible mitigation measures

Appropriate risk assessment: to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.

3.2 Site Specific Flood Risk Assessment

Mapping:

- A location map
- A Plan that shows existing site and proposed development(s)
- Identification of any structures which may influence the hydraulics.
- Flood Inundation map showing flood zone areas on the subject site / area

Surveys:

- Site levels related to Ordnance Datum

- Appropriate cross-section(s) showing finished etc. Or other relevant levels in respect to flooding.

Design Standards

- The FRA should generally be undertaken on the basis of a design event of the appropriate design standard:-
  - 100 year Fluvial Flood or 1% Annual Exceedance Probability (AEP) for River Flow
  - 200 year combined Return Period event or 0.5% AEP for tide affected sites

Assessments:

A site-specific flood risk assessment should in general include the following assessments

- All potential sources of flooding that may affect the site
- Flood alleviation measures already in place
- The potential impact of flooding on the site and consideration of flood zones in which the site falls within and the demonstration that development meets the vulnerability criteria set out in the guidance.
- The potential impact of the proposed development on the flooding and flood risk to other lands and properties.
- How the layout and form of the development can reduce those impacts, including arrangements for safe access and egress, which may include an evacuation plan for the development.
- Proposals for surface water management according to sustainable drainage principles
- The effectiveness and impacts of any necessary mitigation measures
- The residual risks to the site after the construction of any necessary measures and the means of managing these risks

3.3 Decision Making Process

Management of flood hazard and potential risks in the planning system is based on

1. Sequential Approach
2. Justification Test

1. Sequential Approach

The aim of the sequential approach is to guide development away from areas at risk from flooding. The approach makes use of flood risk zones, ignoring presence of flood protection structures, and classifications of vulnerability of property to flooding.

ZONE	DEFINITION
Zone A High Probability – Highest risk of flooding	More than 1% probability of river flooding and more than 0.5% probability of tidal flooding. Development should be avoided and/or only considered through application of Justification test. Only water compatible development, such as docks and marinas, dockside activities that require a waterside location, amenity open space, outdoor sports and recreation and essential transport infrastructure that cannot be located elsewhere would be considered appropriate for this zone (i.e. not requiring application of Justification test).
Zone B Moderate Probability	Between 1 and 0.1% probability of river flooding or between 0.5 and 0.1% probability of coast flooding. Development should only be considered in this zone if adequate land or sites are not available in Zone C or if development in this zone would pass the Justification Test.
Zone C Low Probability	Less than 0.1% probability of river or coastal flooding. Development in this zone is appropriate from a flooding perspective.

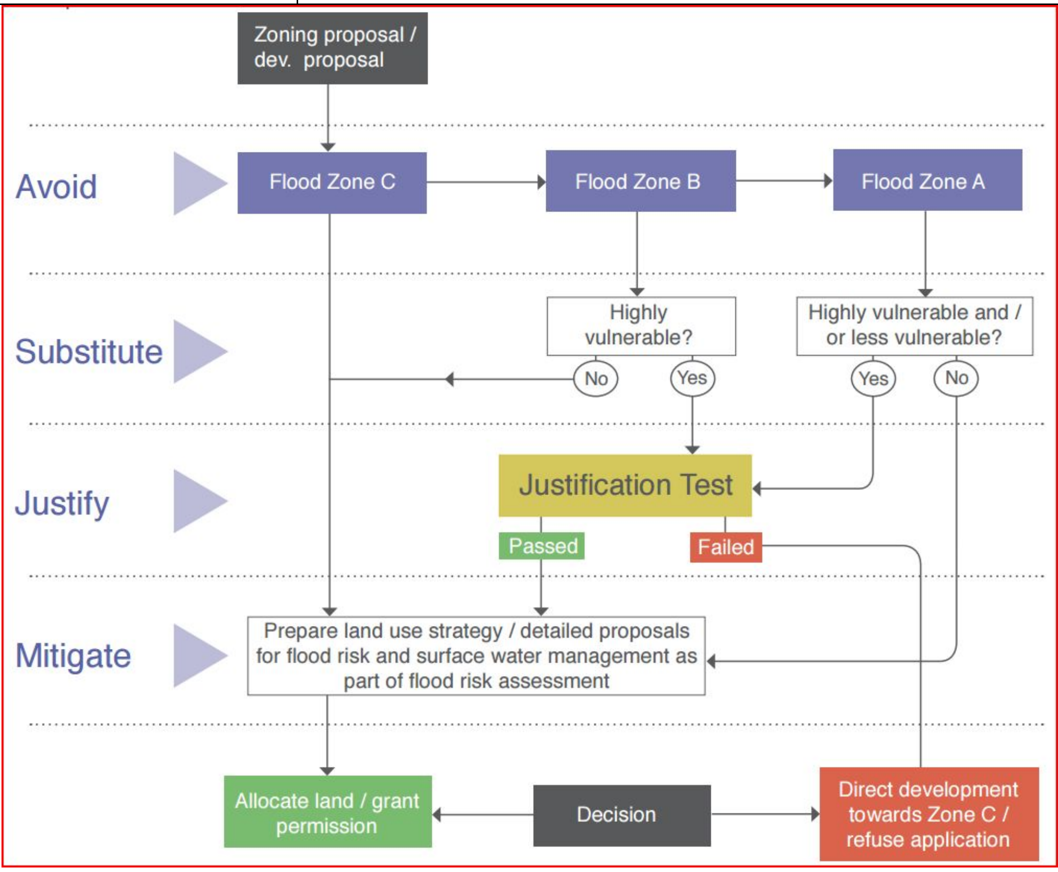

Figure 4 Sequential Approach Mechanism in the Planning Process (copy of Fig. 3.2 from the Planning System and the Flood Risk Management Planning guidelines)

2. Justification Test

Further sequentially-based decision making should be applied when undertaking the Justification Test for development that needs to be in flood risk areas for reasons of proper planning and sustainable development:

1 within Zone or site, development should be directed to areas of lower flood probability;

2 where impact of the development on adjacent lands is considered unacceptable the justification of the proposal or Zone should be reviewed

3 where the impacts are acceptable or manageable, appropriate mitigation measures within the site and if necessary elsewhere should be considered.

Application of the Justification Test in Development management.

Where a planning Authority is considering proposals for new development in areas at a high or moderate risk of flooding that include types of development that are vulnerable to flooding and that would generally be inappropriate, the planning authority must be satisfied that the development satisfies all of the criteria of the Justification Test as it applies to development management outlined in Box 5.1

Box 5.1 Justification Test for development management (to be submitted by the applicant)

When considering proposals for development, which may be vulnerable to flooding, and that would generally be inappropriate as set out in Table 3.2, the following criteria must be satisfied:

1. The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines.
2. The proposal has been subject to an appropriate flood risk assessment that demonstrates:
   (i) The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk;
   (ii) The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible;
   (iii) The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access; and
   (iv) The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.

The acceptability or otherwise of levels of residual risk should be made with consideration of the type and foreseen use of the development and the local development context.

Note: See section 5.27 in relation to major development on zoned lands where sequential approach has not been applied in the operative development plan.

Refer to section 5.28 in relation to minor and infill developments.

Assessment of major proposals for development in areas of flood risk pending implementation of these Guidelines

5.27 From a flood risk management perspective, proposals fitting into this category should be considered as though the land was not zoned for development. In such situations the applicant should be required, in consultation with the planning authority, to prepare an appropriate SFRA and to meet the criteria for the Justification Test as it applies to development plan preparation. The planning authority must then assess the proposal against the Justification Test as it applies to the development management process. Where the information is not sufficient to fully assess the issues involved, the development should not be approved on the basis of flood risk and / or on the grounds of prematurity prior to addressing flood risk as part of the normal review of the development plan for the area.

Assessment of minor proposals in areas of flood risk

5.28 Applications for minor development, such as small extensions to houses, and most changes of use of existing buildings and or extensions and additions to existing commercial and industrial enterprises, are unlikely to raise significant flooding issues, unless they obstruct important flow paths, introduce a significant additional number of people into flood risk areas or entail the storage of hazardous substances. Since such applications concern existing buildings, the sequential approach cannot be used to locate them in lower-risk areas and the Justification Test will not apply. However, a commensurate assessment of the risks of flooding should accompany such applications to demonstrate that they would not have adverse impacts or impede access to a watercourse, floodplain or flood protection and management facilities. These proposals should follow best practice in the management of health and safety for users and residents of the proposal.

3.4 Climate change Allowance

3.4.1 Introduction

There is a high degree of uncertainty in relation to the potential effects of climate change, and therefore a precautionary approach is required. Examples of precautionary approach include:

- Recognising that significant changes in the flood extent may result from an increase in rainfall or tide level and accordingly adopting a cautious approach to zoning lands in these potential transitional areas.
- Ensuring that the finish levels of structures are sufficient to cope with the effects of climate change over the life time of the development.
- Ensuring that structures to protect against flooding (e.g. defence walls) are capable of adaptation to the effects of climate change when there is more certainty about the effects (e.g. foundations of flood defence designed to allow future raising of flood wall to combat climate change).

3.4.2 Climate Change Allowance for Fluvial Flood Flows

Climate change scenarios suggest for UK and Ireland fluvial floods in the 2080's increasing by up to 10% (low and medium low scenarios) or by up to 20% (medium high and high scenarios). Present recommendations are to include in the design flow a 20% increase in flood peaks over 50 years return period as a result of climate change. This scenario based on the Irish growth curve will result in a present day 100-year flood becoming a 25-year flood in approximately 50-years time. The extent and expected levels of flooding are derived based on these flows.

Other predicted climate change effects for the UK are:

- A 4mm to 5 mm per annum rise in mean sea level
- Additional intensity of rainfall of 20%
- An additional 30% Winter rainfall by the 2080's
- A reduction of 35%/45% rainfall in Summer
- The 1 in 100 year rainfall storm to increase by 25%

<u>DEFRA Guidance</u>

In the UK research is ongoing to assess regional variations in flood allowances and the rate of future change. Current research thus far does not provide any evidence for the rate of future change let alone consider regional variations in such a rate. The UK Flood and Coastal Defence Appraisal Guidance (DEFRA, 2006) gives the climate change ranges as per Table 1 below and as a pragmatic approach it is suggested that 10% should be applied up to 2025, rising to 20% beyond 2025.

In Ireland, general practice is to use a medium range climate change allowance for flood flows of 20% over the next 100 years. This rate has been adopted by the OPW for all of its Catchment Flood Risk Assessment and Management Studies (Lee, Dodder, Tolka CFRAMs, Shannon, West, etc.).

UK Flood and coastal appraisal guidance (DEFRA, 2006)				
Parameter	**1990 – 2025**	**2025 - 2055**	**2055 - 2085**	**2085 - 2115**
Peak rainfall intensity (preferably for small catchments)	+5%	+10%	+20%	+30%
Peak river flow (preferably for larger catchments)	+10%	+20%		

Table 1 UK flood and coastal defence appraisal guidance (DEFRA, 2006)

The Flood Risk Planning Guidelines recommends a precautionary approach to climate change effects in respect to flooding due to the high level of uncertainty in predicting its effects. It recommends the following in this respect:

- Caution in zoning lands in these potential transitional areas that would be impacted if climate change predictions occur
- Ensuring that the level of structures designed to protect against flooding are sufficient over the lifetime of the design to cope with the effects of climate change
- Ensuring that structures to protect against flooding and the development are capable of adaption to the effects of climate change when there is more certainty as to the effects

3.4.3 Recommended Climate Change Allowance Guidance for Ireland

Notwithstanding the above precautionary principle, the flood risk zones defined in the Flood Risk Planning Guidelines are based on the present-day assessment of the 100-year (1%) and 1000-year (0.1%) return period for fluvial flooding and the 200-year and 1000-year for tidal flooding. The OPW provide specific guidance as to the allowances in their publication entitled “Assessment of Potential Future Scenarios, Flood Risk Management Draft guidance, 2009 and these allowances are summarised in Table 2.

Table 2 Climate Change Allowances for Future Scenarios 100 year

Criteria	**Mid-Range Future Scenario MRFS**	**High-End Future Scenario HEFS**
Mean Sea Level Rise	+500mm	+1000mm
Land Movement	-0.5mm/year	-0.5mm/year
Extreme Rainfall Depths	+20%	+30%
Flood Flows	+20%	+30%

Mid-range scenario adopted in the CFRAM studies

4. Flood Hydrology

4.1 Existing Site Drainage

The Timahoe North Bog site drainage is achieved by a series of longitudinal field drains spaced approximately 250 m apart running northwest – southeast. Outfall / collector drains are located along the northwest and southeast boundary. There are 11 longitudinal dug drains that carry the drainage water from the bog to the receiving watercourses. These longitudinal drains cross two raised disused rail line tracks where it is understood that small pipe culverts were provided to continue the longitudinal drainage run. At both the northwest and the southeast ends of the bog these drains outfall into the collector drain via small pipe culverts and possibly historically during peat production the water level and water table was artificially lowered by over pumping into the boundary drains.

These drains collect and discharge the local drainage waters generally in a Southwest Direction towards a Southern Collector perimeter drain that outfalls to the Derrylea Stream. The Derrylea Stream forms part of the Mulgeeth Stream that flows past Doran Nursery. Currently the eleven longitudinal Drains in the Bog are not connected to one another and all drain separately out of the bog to the perimeter collector drains via pipe culverts. A site inspection carried out in April 2018 has identified that all eleven of the longitudinal drains have culvert connections with the southern collector drain and these culvert connections are active and generally of size typically 300mm to 450mm diameter. There is also evidence under the disused rail line track that a similar arrangement is in place.

At the northwest end of the bog a number of these longitudinal drains discharge northwest towards a tributary stream of the Fear English River. It should be noted that the proposed Solar Farm development areas all drain southeast via the longitudinal drains to the Southern Collector Drain and will not affect the existing drainage at the northwest end of the Bog.

At present time it is difficult to assess the condition of the various pipe culverts under the disused rail line tracks and downstream south-eastern embankment and also the outfall drainage details with the majority of the wide field drains having standing water and such pipes submerged or covered by sediment etc. The lands to the north of the second (most northerly) disused rail line track drain north-west to the Fear English River system. The lands between the two disused rail line tracks and the lands to the south of the first disused rail line track drain south-east into the Mulgeeth stream. There is a lower more permanent wet area in the middle of the site and predominantly to the south of the first disused rail line track.

Typical summer drainage levels in these drains vary from drain to drain with the outer drains to the east and west being more elevated at 79.5 to 80.5 m OD and the drains to the middle of the site at 77.5 to 78.5m OD. In wet periods a lake forms in the middle of the site forming levels of c. 79m OD and extending over a large area. This flooding suggests that the outfall capacity from the site is restricted with water levels having to build-up before achieving sufficient flows.

The longitudinal Drains are labelled D1 to D11 from southwest to northeast and typically have base width of 1 to 2m , 1.5m deep and 6 to 10m Topwidth. Using a drain full cross-section area of 7m^2 the available volume within the drains and the drainage catchment is presented below in Table 3.

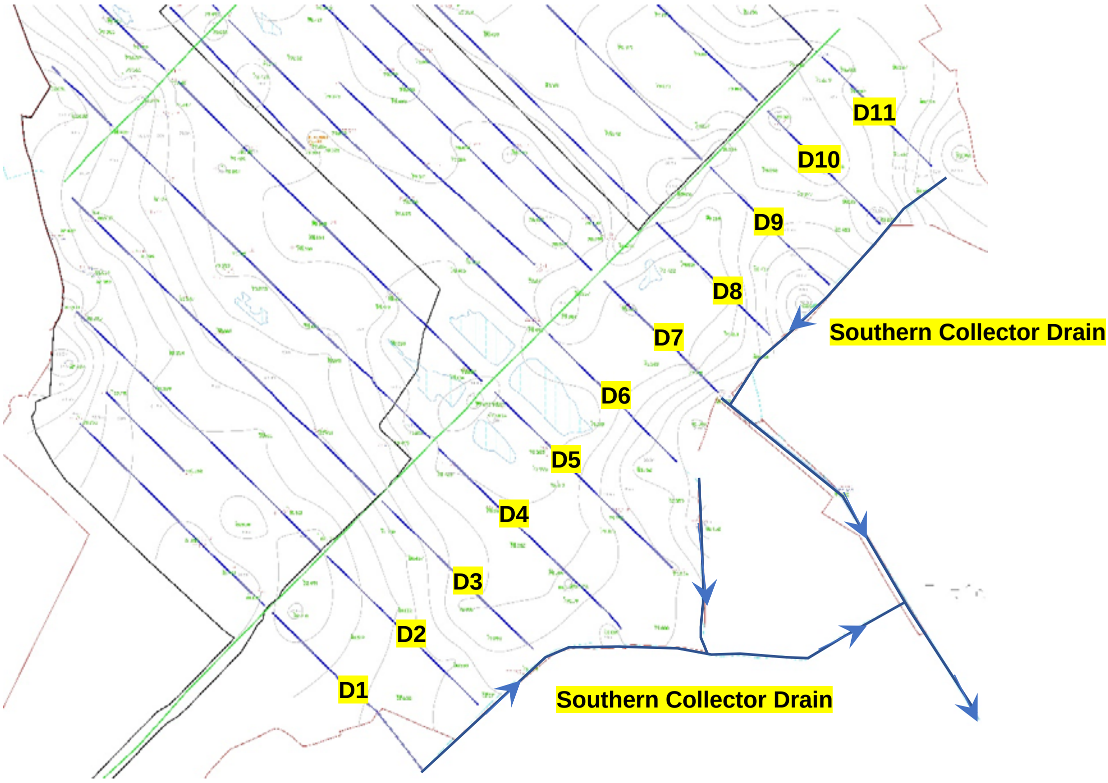

Figure 5 Longitudinal Drains and Southern Collector Drain

Table 3 Description of Longitudinal Drains

Reference	Contributing Area (ha)	Drain Length (m)	Drain Storage Volume (m3)
Drain 1	42.22	1510	10,570
Drain 2	43.37	1740	12,180
Drain 3	48.32	1997	13,979
Drain 4	54.93	2262	15,834
Drain 5	55.41	2260	15,820
Drain 6	52.1	2052	14,364
Drain 7	49.55	2067	14,469
Drain 8	46.73	1953	13,671
Drain 9	59.31	2313	16,191
Drain 10	59.62	2355	16,485
Drain 11	49.5	2459	17,213

Note green shading indicates drains traversing through Solar Farm Development site areas

4.2 Estimation of Flood Flows

The study site catchment area is c. 7.5km^2 and is a self-contained area with no external surface water inflows and only the direct rainwater falling on the site contributing to flows and water levels, refer to Figure 6. Most of the longitudinal drains are partially blocked and rainwater falling on the site is significantly attenuated on the site both upstream and downstream of the disused rail line track. This causes flood waters to rise flooding out large areas on the Bog until l it slowly drains away to the Mulgeeth tributary. The natural outflow from this bog site to the Mulgeeth stream is restricted due to the almost flat gradients on the bog and the lack of hydraulic connectivity between drainage channels. This suggests relatively low greenfield runoff rates from the site.

This site is ungauged in respect to flood flow estimation and requires ungauged flood estimation methods to determine the greenfield runoff rate and the return period design flows. The Flood Studies update method for estimating flood flow magnitudes based on physical catchment descriptors estimates a median Flood flow magnitude of 0.063cumec per km^2 for a SAAR = 800mm, BFISOIL = 0.3613, FARL = 1, DRAIND = 0.197km/km^2 and S1085 = 0.1m/km.

The return period flood growth curve based on the FSU Pooling group method using EV1 (extreme value type 1, Gumbel) distribution gives the following Return Period flood growth factor relationship:-

Table 4 Flood Flow Growth Curve for the Mulgeeth Tributary Stream

Return Period T years	Growth Factor XT = QT/Q2
2	1.0
10	1.74
100	2.67
1000	3.58

This presents a relatively steep growth factor with the flood growing significantly with return period.

For a catchment area of 7.5km^2 the annual flood discharge from the Timahoe North catchment is 0.47cumec and at a statistical standard error this discharge rate at 67% confidence interval will vary from 0.33 to 0.64cumec. The estimated 100 year and 1000 year flows from the bog are 1.25 and 1.71cumec.

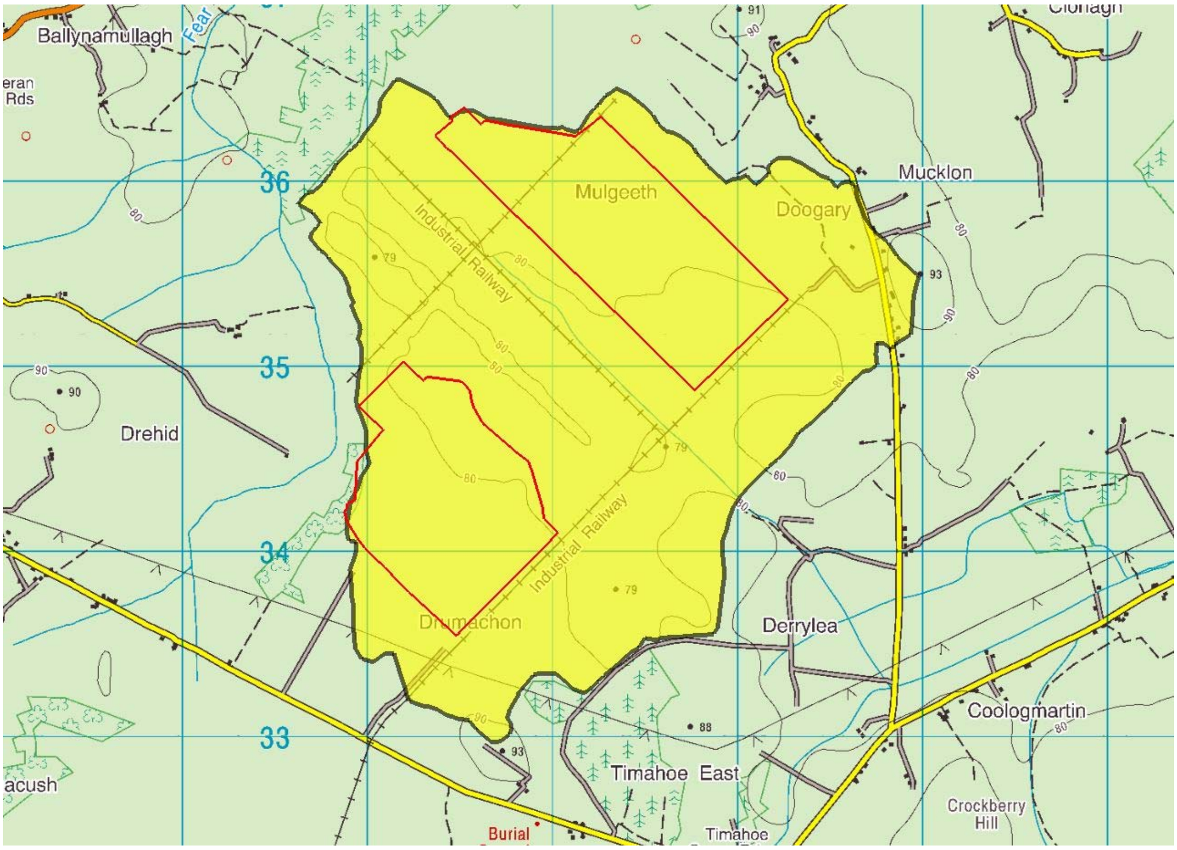

Figure 6 Catchment Area of Site contributing to outflow from the Timahoe North Site.

The catchment area of the Mulgeeth Stream to the local road adjacent to Doran's Nursery is 19.7km^2 and the FSU estimated median (2 year) flood based on ungauged physical catchment descriptor (PCD) estimation equation is 0.99cumec and the 100 year and 1000 year return period estimates are 2.64 and 3.54cumec.

The return period flood growth curve based on the FSU Pooling group method using EV1 (extreme value type 1, Gumbel) distribution gives the following Return Period flood growth factor relationship:-

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For a catchment area of 7.5km^2 the annual flood discharge from the Timahoe North catchment is 0.47cumec and at a statistical standard error this discharge rate at 67% confidence interval will vary from 0.33 to 0.64cumec. The estimated 100year and 1000year flows from the bog are 1.25 and 1.71cumec based on the FSU data.

4.3 Rainfall Measurements at Timahoe North

A rain gauge was installed close to the central Drain 7 and upstream of the disused rail line track in January 2018. This gauge recorded cumulative rainfall amounts averaged over 15minute intervals for the gauged period (3rd Jan to 22nd March 2018). From this data the maximum recorded 1 day rainfall depth for the gauged period (3rd Jan to 22nd March 2018) was 21.8mm and the maximum 4 day was 28.4mm.

4.4 Storm Rainfall at Timahoe North

Extreme rainfall depths for the Timahoe North site were determined using the Met Eireann 20 km by 20 km model of rainfall depth-duration-frequency and applied over the entire subject site area using the OPW FSU web portal method. The rainfall totals for the bog at different durations and return periods are presented below in Table 6.

Table 6 Storm Rainfall Depth-Duration-Frequency for Timahoe North

Duration hrs	Return Period T years			
	2	**10**	**100**	**1000**
6	20.3	32.6	54.4	89.2
12	26.7	41.8	68	108.9
18	31.3	48.3	77.5	122.2
24	34.9	53.4	84.8	132.5
36	38.1	57.2	89.1	136.6
48	41.1	60.9	93.5	141.1
72	46.6	67.7	102.1	151.4
96	51.5	74.1	110	161.1
120	56.2	80	117.5	170.3
144	60.6	85.6	124.6	179.1
192	69	96.1	138	195.7
240	76.8	106	150.6	211.2
360	95	128.7	179.3	246.9
480	112	149.8	205.8	279.6
600	128.2	169.8	230.8	310.2
720	143.6	188.7	254.3	338.7
840	158.2	206.5	276.3	365.1
960	172	223.2	296.8	389.4
1080	185	238.8	315.8	411.6
1200	197.2	253.3	333.3	431.7
1300	206.8	264.5	346.7	446.8
1400	215.8	275.0	359.1	460.5
1500	224.2	284.7	370.5	472.8
1600	232.1	293.7	380.8	483.5
1700	239.4	301.9	390.1	492.8

The growth curve derived for the short duration rainfall events is similar to the FSU method presented earlier. The longer duration events have a lower growth factor, as expected.

The long-term annual rainfall (SAAR) for the site is 800mm and losses via evapotranspiration are approximately 480mm based on nearest Met Eireann Meteorological Station.

Table 7 Computed flood growth factors from catchment rainfall totals

Duration days	Return Period		
	10year	100year	1000year
0.5	1.57	2.55	4.08
1	1.53	2.43	3.80
2	1.48	2.27	3.43
4	1.44	2.14	3.13
6	1.41	2.06	2.96
8	1.39	2.00	2.84
10	1.38	1.96	2.75
15	1.35	1.89	2.60
20	1.34	1.84	2.50

The return period Rain Storm design Event is the 100 year and 1000 year 24 hour rainfall depth within a 1 to 5 day duration 100 year and 1000 year rainfall depths, refer to Figures 7 and 8.

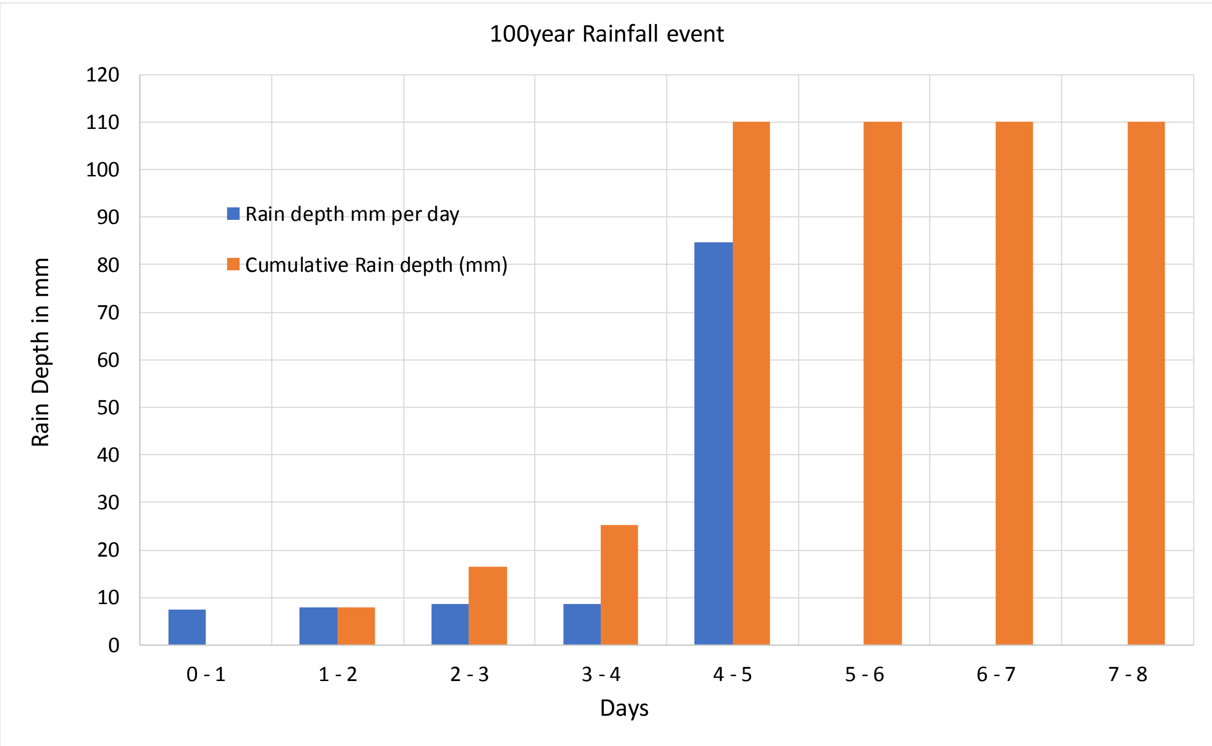

Figure 7 100year 24hour rainfall depth with cumulative 1 to 5 day 100year rain depth totals

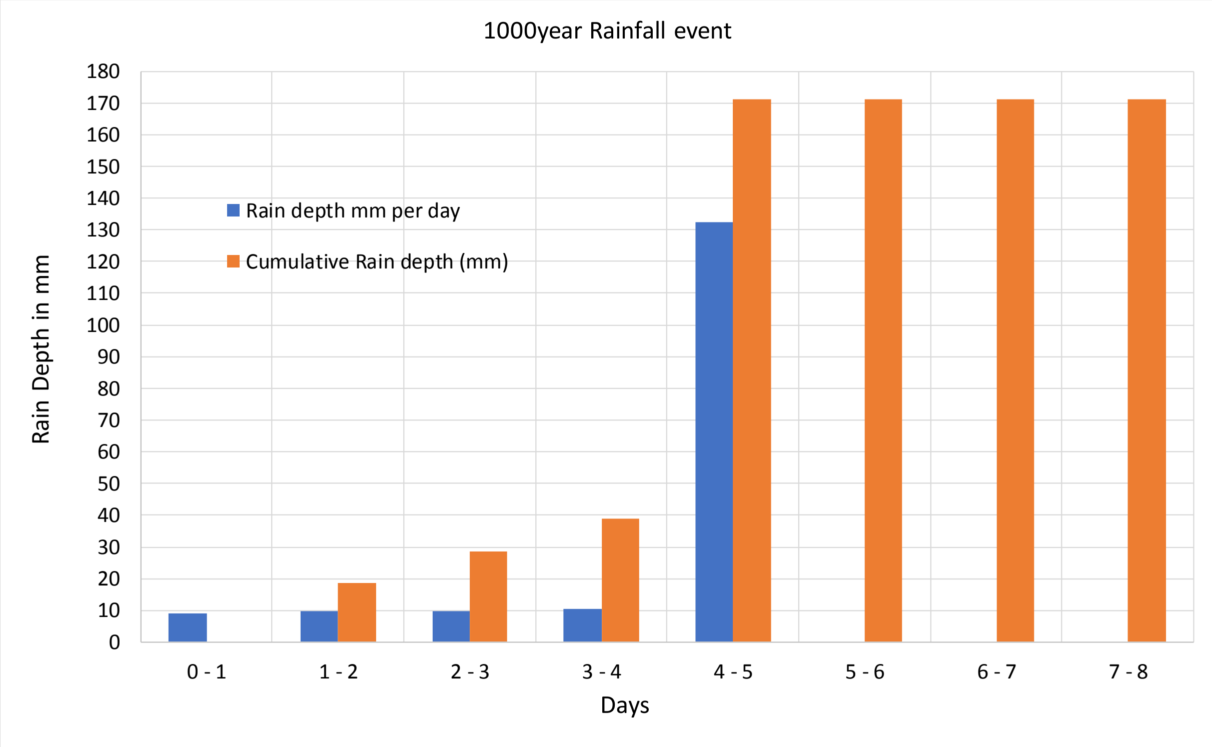

Figure 8 1000year 24hour rainfall depth with cumulative 1 to 5 day 1000year rain depth totals

4.5 Flood Storage at Timahoe North

A lidar survey at 2m grid interval of the entire site was used to determine the flood volume available in the bog at a particular water elevation. This information is presented in the following Table 7 for the entire site area (north, middle and south sections) and also the area that drains southwards (i.e. includes middle and south sections only) excluding the area north of the second disused rail line track that drains northwards to the Fear English River system.

Table 8 Timahoe North Stage - Storage Volume Relationship

Stage Elevation m OD Malin	Entire Bog m³	Middle and southern sections m³
78	42,000	39,000
78.25	95,000	89,000
78.5	186,000	172,000
78.75	346,000	313,000
79	609,000	540,000
79.25	983,000	855,300
79.5	1,473,000	1,267000
79.75	2,071,000	1,761,000
80	2,775,000	2,326,000
80.25	3,568,000	2,951,000
80.5	4,446,500	3,622,000

The above table shows that significant storage is available at Timahoe North above a flood level of 79m OD which will limit the potential maximum flood level in the Bog and at the proposed solar sites. At 80m OD 2.775 million m^3 of storage is available which is equivalent to c. a 60-day 100 year event assuming no outflow from the bog in that period.

4.6 Water Level Survey at Timahoe North

The water level survey carried out in mid-March 2018 by BNM indicates that longitudinal drains are not hydraulically connected to one another discharging southwards to the Collector Drain at the bog's southern perimeter. The survey showed that the outer drains (1 and 2) have the highest water level with an elevation of almost 80m OD just upstream of the disused rail line track located at the downstream end of the SW solar site. These water levels are caused by high downstream water levels in the southern perimeter collector drain of elevation 79 to 79.5m OD and added to by channel resistance and backing up by the small 300 mm culverts that connect the longitudinal drains 1 and 2 to the southern collector drain. Drain 3 and 4 have water levels of 78.1 to 78.5m OD immediately upstream of the disused rail line track. It is likely that these culverts could be potentially partially blocked by peat debris.

The previous summer July 2017 survey carried out by BNM gave a water level in Drain 1 of c. 80.0m OD upstream of the disused rail line track and 80.645m OD in Drain 2. The gauge recorder G2 located in Drain 2 gave a water level of c. 81m

OD during March 2018 which agrees with the summer 2017 level but contradicts the March 2018 level of 79.7m OD. (c. 1m difference).

The gauged water level monitoring at the five gauged sites carried out from 3 Jan to 22 March 2018 gave maximum flood level and range as follows:

Table 9 Gauged water levels at Timahoe (January – March 2018)

Gauge	Range m	Max level mOD
G1	0.42	78.01
G2	0.46	81.2
G3	0.44	77.85
G4	0.45	78.95
F1	0.59	76.99

Figure 9 Water Level and rain Gauge sites at Timahoe North

5. Flood Risk Assessment

5.1 Drainage

The proposed Timahoe north site is a cutaway raised bog with currently unmaintained drains giving rise to locally high water levels within the drains and saturated soil conditions. Areas of the Bog have been worked and elevations lowered giving rise to local depressions that can pond during prolonged rainfall and slowly drains away.

Essentially this bog is drained by 11 No. long longitudinal drains that outfall southeast to a collector drain of the Mulgeeth stream. Each of these drains effectively drains a width of 250m over a distance of 2 to 2.5km. At the downstream end of these longitudinal drains the outfalls to the collector drain are small and restricted. In many cases it is not possible to determine the pipe connection as they are unmaintained, submerged and possibly blocked and in some cases no outfall connection was provided. Typical sizes of these pipe culvert outfall connections are small pipe diameters of 300 to 450mm.

Anecdotally it was indicated that during peat production over-pumping from these drains was carried out to temporarily draw down the water level during peat extraction periods. These longitudinal drains are also culverted under the raised disused rail line tracks using similar small pipe sizes of 300 to 450mm in diameter and in many cases there is a high likelihood that these culverts are partially blocked and restricting flow. The measured water levels in these drains were generally between 77.7 and 80m and in the outer two drains to the west water levels locally exceeded 80 and 81m respectively.

5.2 Hydrodynamic Modelling of Existing Flood Risk

The Bog system at Timahoe North represents a complex drainage system in respect to estimating return period flood levels within the Bog, particularly as the bog drains via eleven separate longitudinal drains to a perimeter collector drain. In order to quantify the existing (pre-development) and proposed (post development) flood risk at the respective Solar Sites a detailed 2-dimensional hydraulic model of the Bog was developed.

The software of choice for this application was TELEMAC2D. The TELEMAC hydraulic software package is a highly regarded, and peer reviewed in International hydraulic journals hydraulic software system and used widely internationally. The hydraulic Software solves the shallow water equations in 2 dimensions on the horizontal plane and is depth average in the vertical. It allows for variable density meshing to be applied for effective and efficient definition of channels and floodplain areas and includes for culverts/siphons between specified computational nodes. The mesh size is 41,549 nodes and 82,227 elements with a general flood plain element size of 12.5 m between nodes, refer to figure 10 and 11. Typically within the longitudinal channel and for the downstream collector drains 5 nodes across the channel width (7.5 to 10 m) are used, (left top of bank, left bottom of bank, middle of drain, right bottom of bank and right top of bank) and a longitudinal spacing of 20 to 25 m, refer to Figure 11.

Rainfall is used to drive the model with rainfall intensity in mm/sec applied at all of the computational nodes in the domain. The 100 and 1000 year rainfall profiles are presented in Figures 7 and 8.

The downstream channel flow-stage relationship is specified at the downstream stream channel boundary of the 2D Model.

A Manning roughness of 0.08 is specified for both channel and floodplain alike, representing a moderately rough surface associated with the relatively dense vegetation generally present on the bog and within the drains.

The ground elevations specified at each model nodal point were obtained from channel topographical survey carried out by BNM in 2017 and from available 2m resolution DTM Lidar aerial data, refer to figure 12 and 13. All existing culvert sizes were assumed to be 0.3m in diameter, submerged but acting at full bore capacity. entrance (0.5 shock loss coefficient), exit (1.0 shock loss coefficient) and friction loss (Manning’s n = 0.08) coefficient were specified in the model.

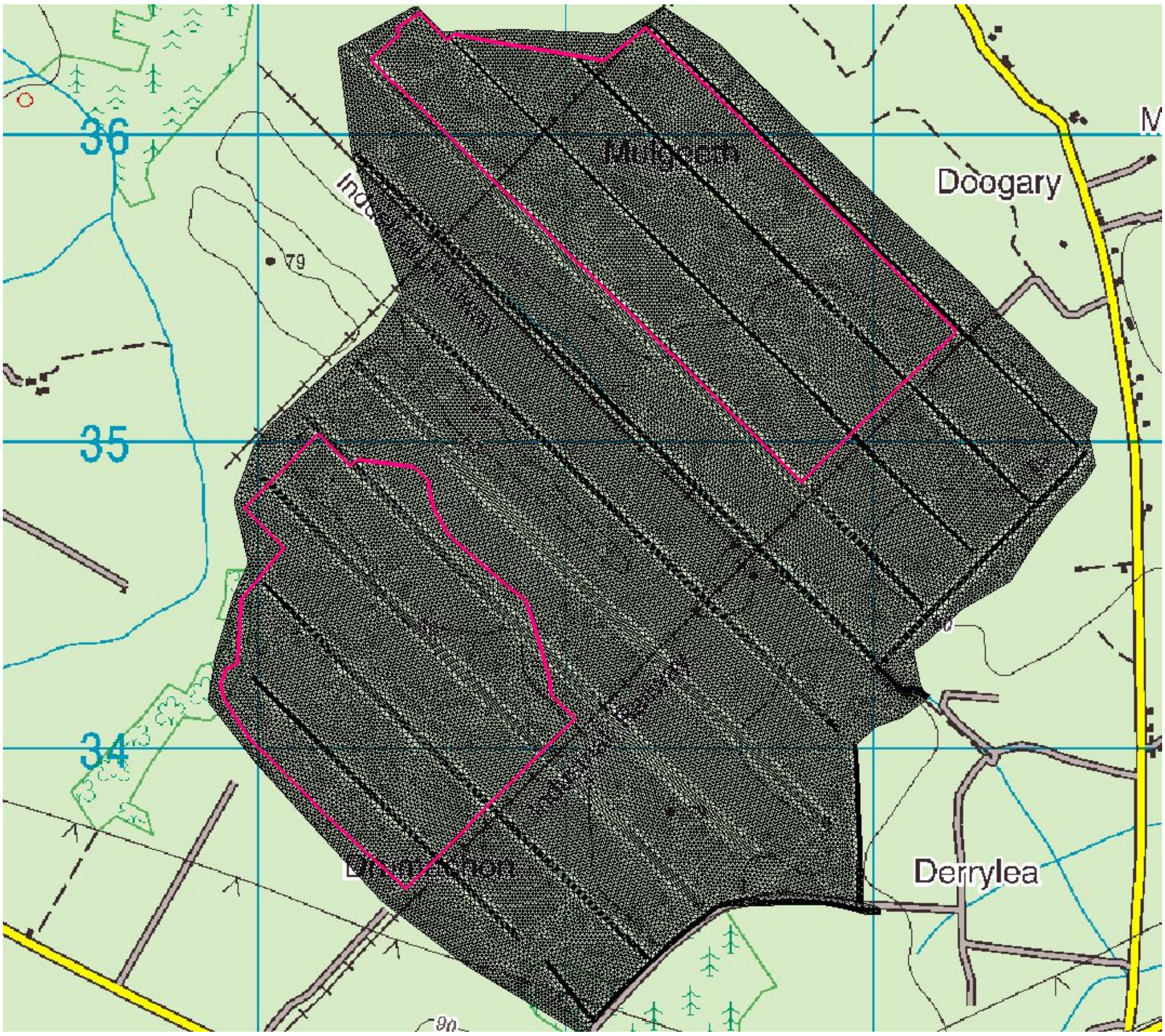

Figure 10 Finite element model domain and variable mesh (note elements used to define drains elongated in the longitudinal direction

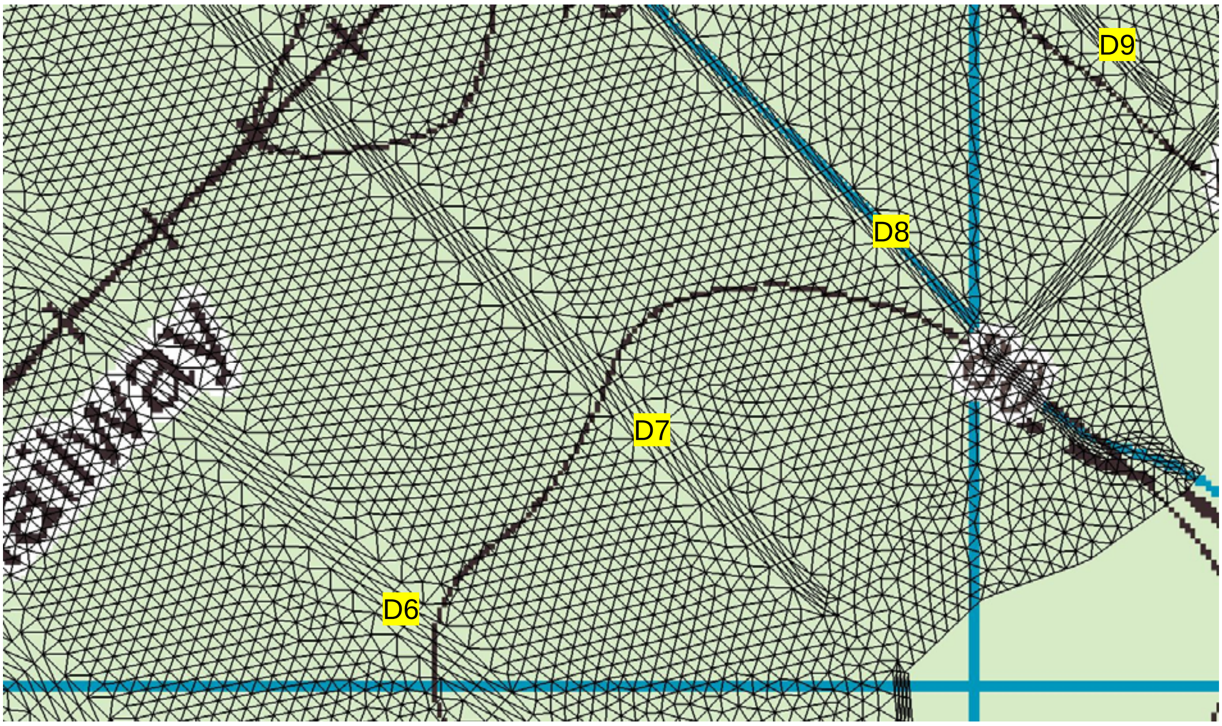

Figure 11 View of variable meshing associated with the longitudinal channel and collector drain

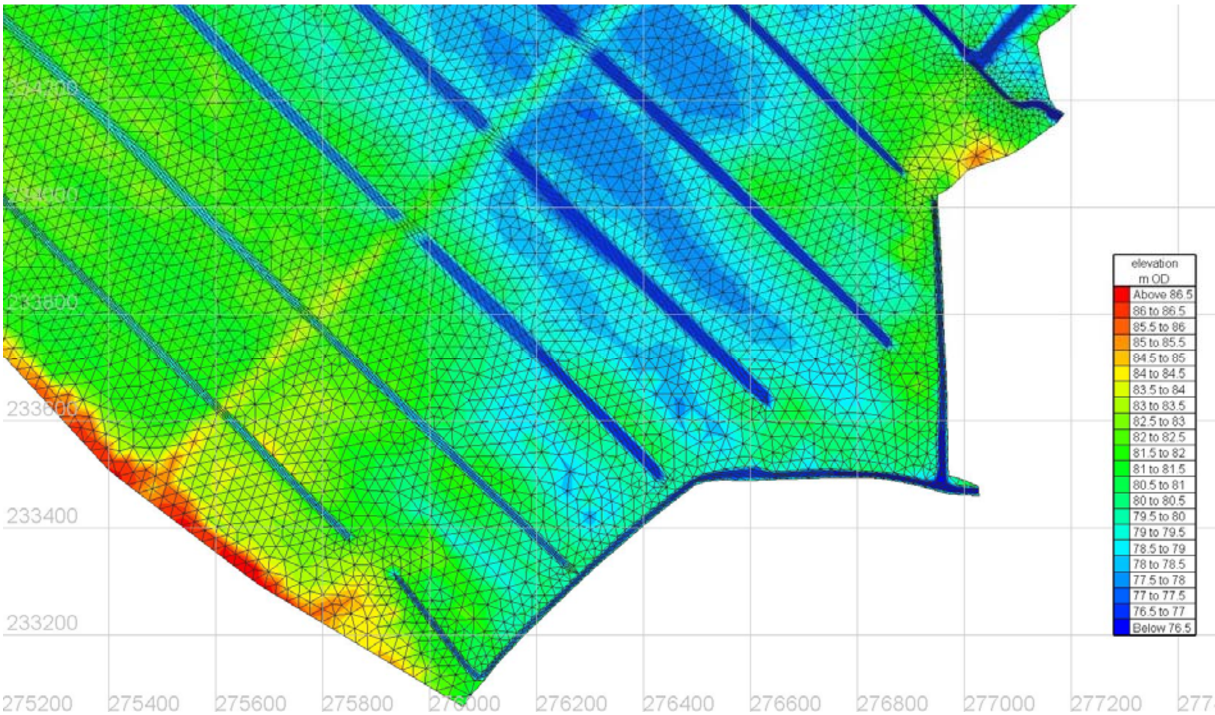

Figure 12 view of model bathymetry towards southern end of Bog

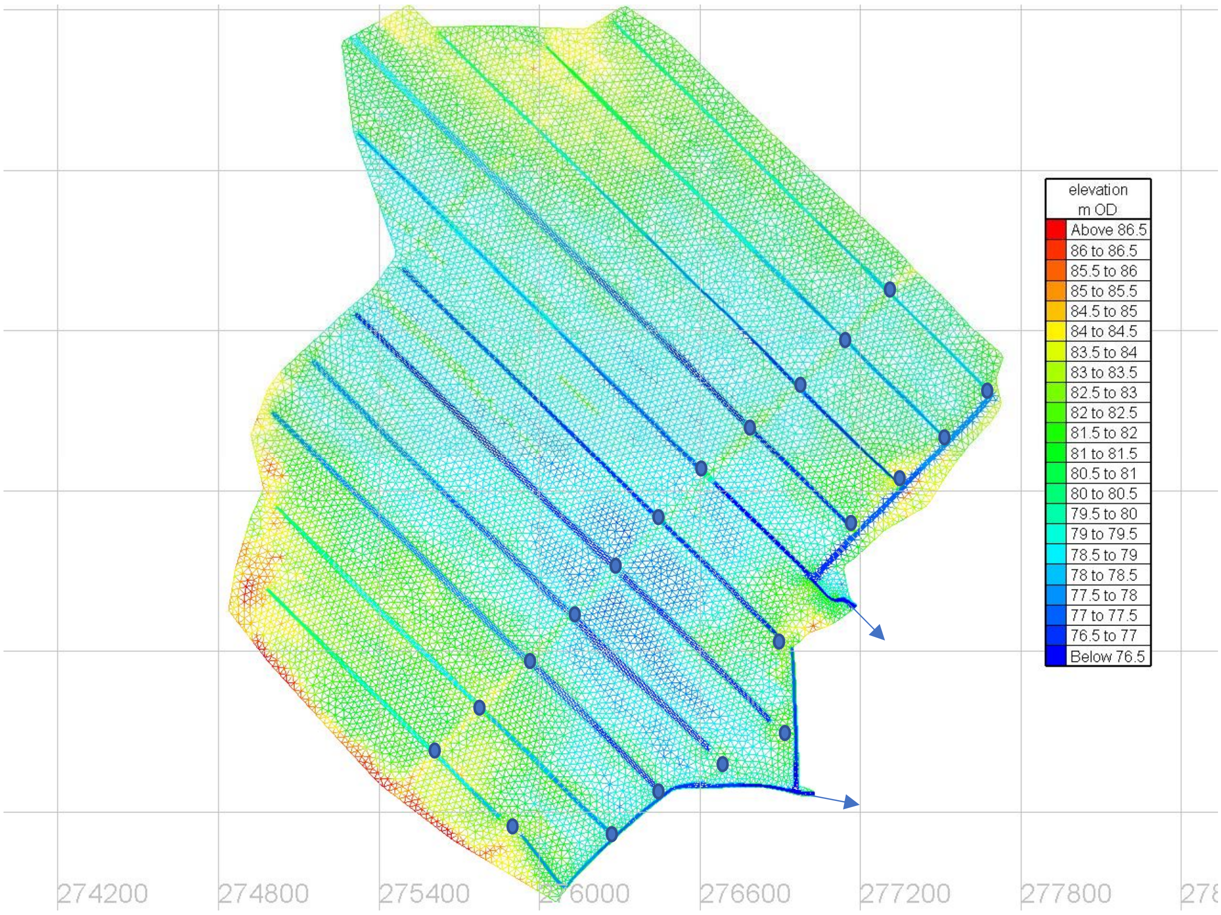

Figure 13 View of specified 300mm dimeter pipe culverts included in hydraulic model of existing Bog drainage system

Figure 14 Aerial View of Bog Showing generally Dry conditions within both Solar Site areas

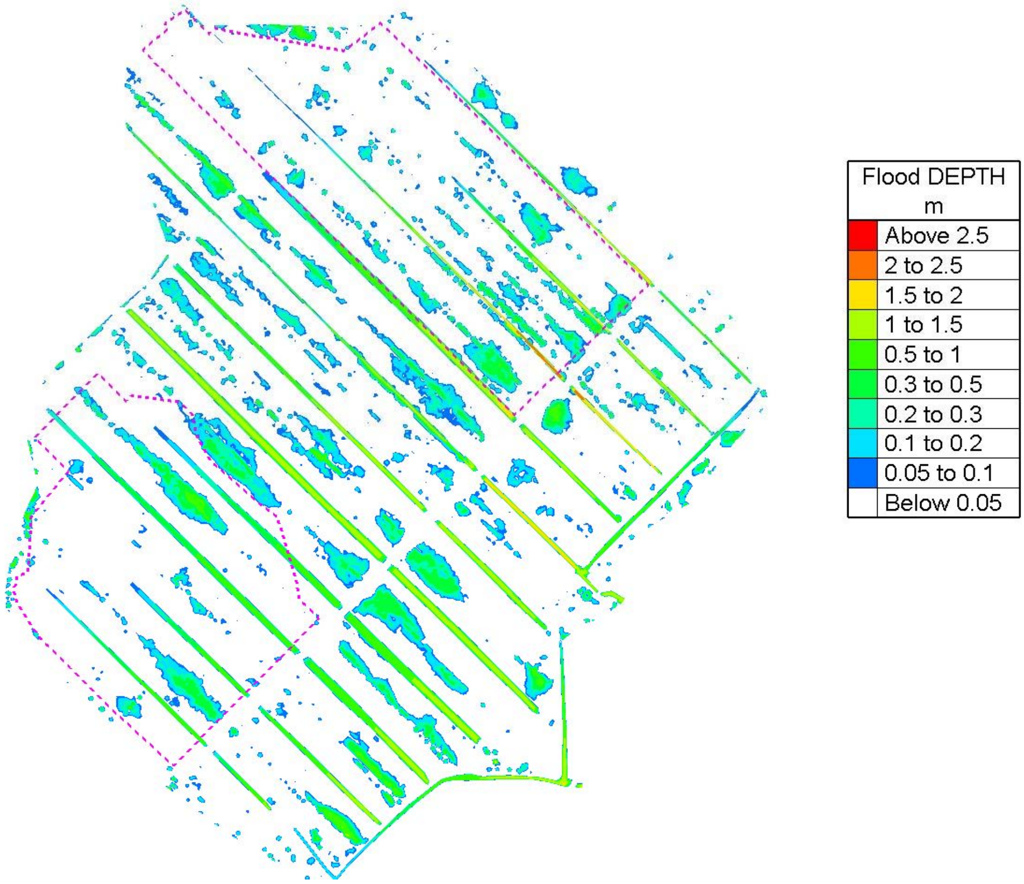

Figure 15 Computed Water Depths at 10 year Rain Storm Event – Existing Case

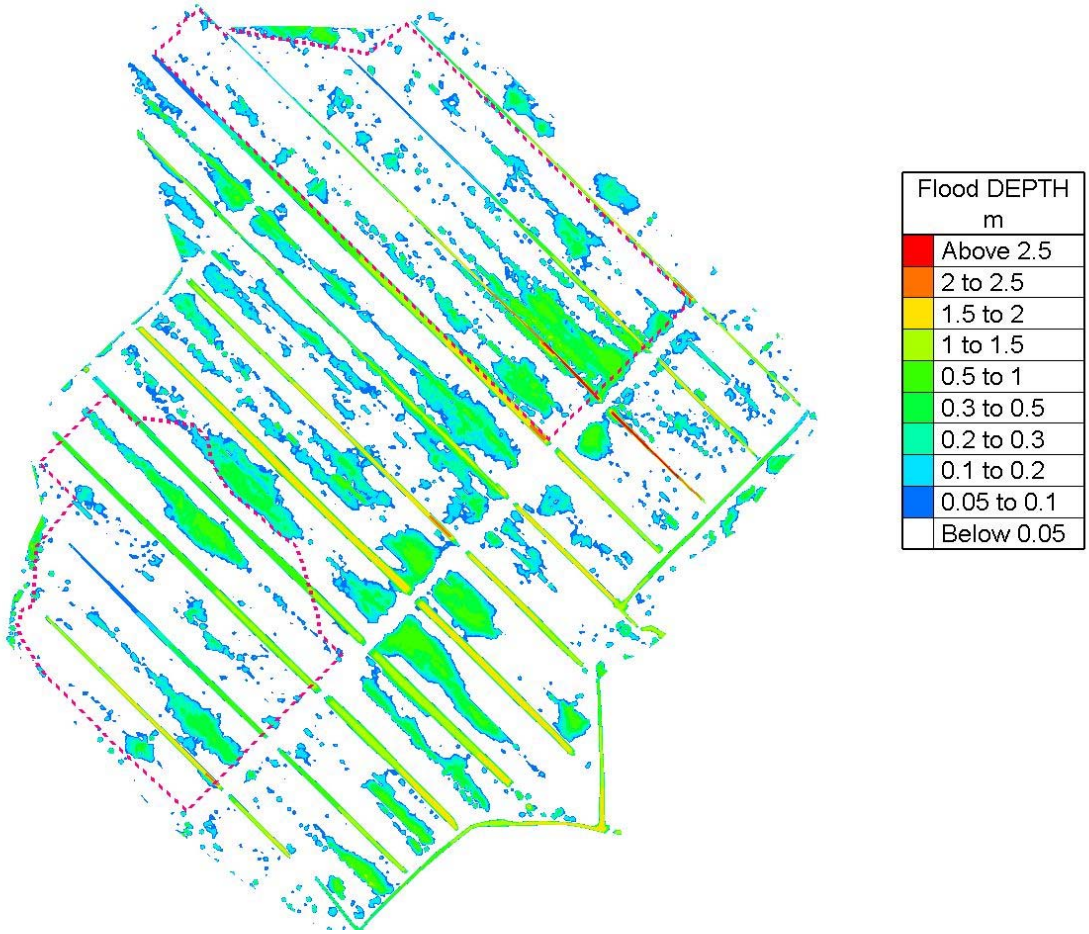

Figure 16 Computed Water Depths at 100 year Event – Existing Case

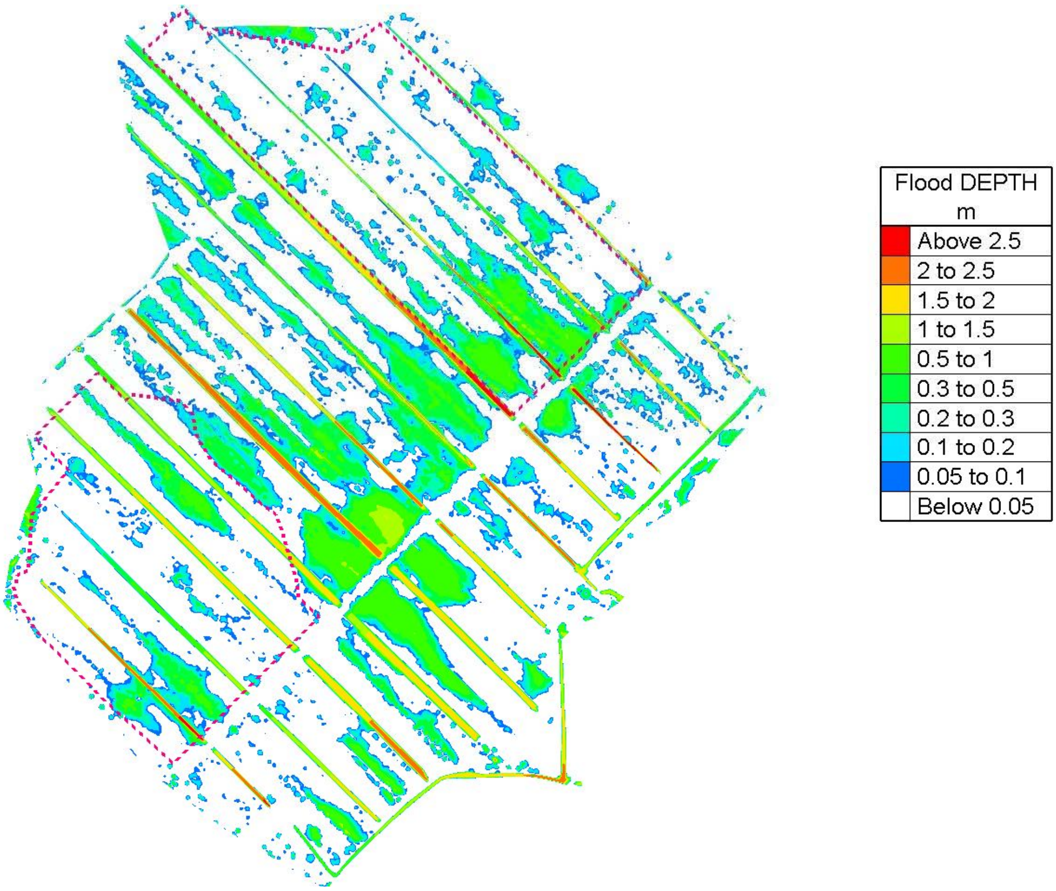

Figure 17 Computed Water Depths at 1000 year Event – Existing Case

Table 10 Computed Return Period Flood Levels in longitudinal drains upstream of disused rail line track

Reference	10year max Flood Level m OD	100year max Flood Level m OD	1000year max Flood Level m OD
Drain 1	80.99	81.10	81.67
Drain 2	80.41	80.52	80.90
Drain 3	78.25	78.69	79.33
Drain 4	77.82	78.23	78.88
Drain 5	77.67	78.20	78.87
Drain 6	78.01	78.64	78.87
Drain 7	78.51	78.86	79.04
Drain 8	78.18	78.86	79.33
Drain 9	79.08	79.59	79.70
Drain 10	79.48	79.60	79.71
Drain 11	79.76	80.16	80.21

Note green shading indicates drains traversing through Solar Farm Development site areas

Under the existing 10year, 100 year and 1000 year flood events the peak outflow from the bog was computed to be 1.09, 1.59 and 1.96cumec respectively. Contour Plots of computed flood depths for these flood events under the existing case is presented in Figure 15 to 17 respectively. Within the Solar farm sites out of bank flooding is associated with pluvial ponding of rainwater in locally lowered peak excavated areas.

The predicted peak water levels upstream in the Solar Farm sites vary from 78.23 to 81.10 at the 100 year and from 78.88 to 81.67 at the 1000 year return period events.

5.3 Flood Risk Zone Classification

The proposed Solar Farm Sites 1 and 2 are located on a cutaway raised bog which has restricted drainage and poor permeability soils giving rise to a highwater table throughout the site. The proposed solar sites are located on lands with elevations varying from 78.5 to 83 m OD excluding the drainage channels which are lower. The flood level in individual longitudinal drains is dictated by the presence and condition of the small culverts under the disused rail line track and downstream perimeter embankment / access track and the flow capacity within the southern collector drain. Such drainage condition can change and without maintenance could deteriorate further giving rise to higher water levels in the bog under the existing situation.

The 2-dimensional hydraulic model of the Timahoe Bog and drains was run for 100 year and 1000 year return period rainstorm events shown in Figure 7 and 8. The resultant flood inundation map for the existing case is shown in Figure 18. The dark blue colour represents the 100 year flood area and the light blue (cyan) colour represents the 1000 year Flood Area. This mapping includes pluvial ponding of rainwater in local depressional areas within the Bog as predicted by the 2-dimensional model. Pluvial flood risk is not considered critical as it is very shallow, localised and can easily be drained.

Under the existing 100 year and 1000 year flood events the peak water levels in the drains at the Solar Farm sites located upstream of the disused rail line track varies from 78.23 to 81.10 for the 100 year and 78.88 to 81.67 at the 1000 year events. The lower levels are predicted in the central area of the Bog.

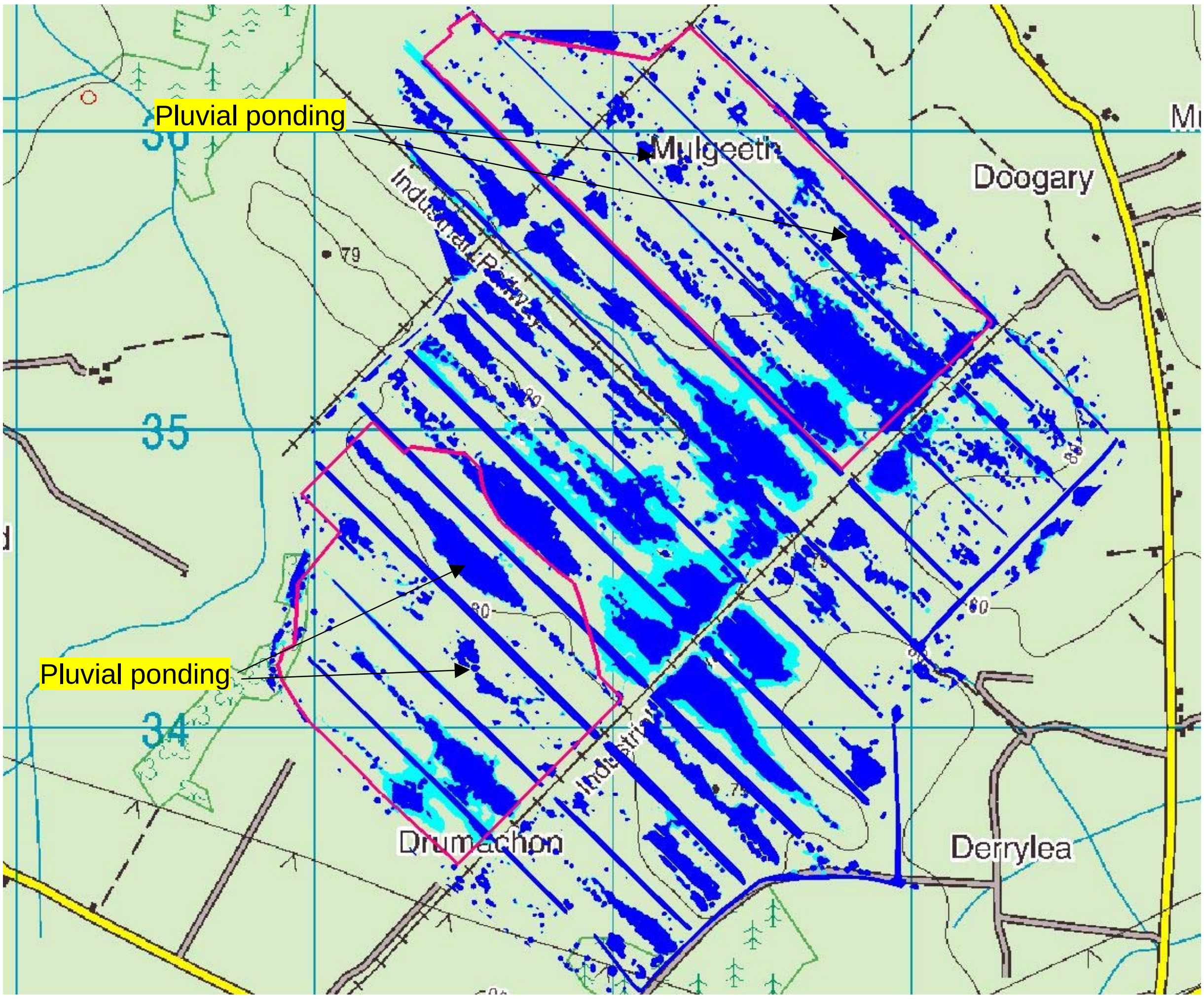

Figure 18 Flood Zones at Timahoe North Solar sites –existing case **(Blue – Flood Zone A, Cyan Flood Zone B and transparent Flood Zone C).**

5.4 Flood Risk Management

The two solar development sites within the BNM Timahoe North Bog (NE and SW sites) have been selected on generally higher drier ground to avoid the lower-lying, flood prone areas of the bog which are associated with the central section of the bog and thereby reduce exposure to flood risk through avoidance, refer to Figure 3 and 14.

The drainage of the bog land can be engineered to reduce potential flood risk to the solar farm development to an acceptable risk level whilst meeting the hydro/ecological requirements and ensuring that the proposed development does not cause unacceptable impact to flood risk elsewhere.

Under existing drainage conditions the proposed solar development has a significant residual flood risk associated with potential blockage to individual longitudinal drains, particularly at the small pipe culverts under the disused rail line track and under the south-eastern perimeter embankment. These longitudinal drains flow southeast through 2 small submerged culverts on ten of the eleven drains and a single culvert on drain 7. This represents 21 culvert sites of potential blockage.

To reduce elevated flood levels in individual longitudinal drains through the Solar Sites (particularly, drains 1 and 2 and 10 and 11) and to minimise the exposure to residual risk from blockage the following drainage infrastructure is proposed:

- Storm water drainage system of open trenches to collect rainwater falling onto the panels and access tracks, etc. and conveying laterally to the Longitudinal Drain.

- A large transverse connector drain to be located upstream of and running parallel to the access track. The function of this large transverse drain is to connect all longitudinal Drains to one another so that drainage waters can migrate unimpeded towards Drain 7 (refer to Figure 5 for drain numbering). This collector drain is proposed so that drainage of both solar sites can be achieved without residual risk from blockage of the existing smaller pipe culverts on each longitudinal drain under the disused rail line track.

- A new oversized culvert under the disused rail line track on drain 7 to transmit unrestricted flow downstream. The recommended culvert size under the disused rail line track to convey all drainage waters downstream without restriction and avoid blockage and sedimentation problems is a 2.4 by 2.4m box culvert section.

- To manage and control the flood outflow from the bog, so as not to exceed existing flood runoff rates downstream in the Mulgeeth Stream a flow control structure is required on the outlet of drainage channel (D7). This flow control structure is a single 900mm diameter culvert with a concrete spillway set at a crest level of 79.5m OD Malin. The flood control structure will be designed to throttle flood flows from the site so as not to exceed the existing flood flows. Under the existing 100 year and 1000 year Flood events the peak outflow from the bog was computed to be 1.59 and 1.96cumec respectively for the existing drainage case. Simulations show that for the proposed case with the 900mm diameter culvert throttle the outflow from the bog will be 1.49cumec and 1.78cumec at 100 and 1000year return period respectively.

- All other pipe outlets (10 number) in the longitudinal drains that outfall to the southeast collector drain will be sealed off.

- To prevent unnecessary draining of the bog during non-flood periods check dams will be provided in the proposed transverse connector drain downstream of each of the longitudinal drain that is intercepted. These check dam will be installed with a crest level of 78m OD and therefore water will be retained in drains at this level throughout the year to minimise potential for drying. (Consideration can be given to higher check dam level for the more remote drains provided they are below design levels on the site).

- To avoid any potential flood risk the solar panels, access road and inverters which are in flood prone areas to be raised above the predicted 1000 year flood level with CC for the proposed case. The peat repository areas, substation and the compound area are to be located on more elevated land above the predicted 1000 year flood level.

5.5 Hydrodynamic Modelling of Proposed Development Case

The TELEMAC2D hydraulic model was run for the proposed case. The proposed case used the same grid structure as the existing with each subsequent longitudinal drain hydraulically connected upstream of the disused rail line track by including an unrestricted pipe connection between adjacent drains and setting the invert at 78m OD to represent a transverse drain with check dam control. The downstream 300 mm diameter culvert connection with the southeat perimeter collector drain were closed off and the central drain 7 had a 2.4 by 2.4 box culvert included under the disused rail line track in place of the existing 300mm culvert and a 900mm diameter culvert at the outlet of the bog included to throttle the larger 100 year and 1000 year flows.

The computed flood depths are presented in Figures 19 and 20 for the 100 year and 1000 year cases and maximum flood elevations at each drain upstream of the disused rail line track are presented in Table 11.

The computed peak outflow rate for the proposed case with the 900mm diameter throttle at the single outlet point is 1.49cumec and 1.78cumec which are slightly lower than the existing case.

Under the proposed case the computed peak water level in the drains at the Solar Farm sites for the 100 year and 1000 year flood events vary from 78.73m to 79.07m for the 100 year and 79.11m to 79.45m for the 1000 year.

For a separate simulation that included 30% increase in the 1000year Rainfall event the predicted maximum flood levels at the Solar sites were 79.29 to 79.52m OD Malin.

The recommended design Flood Level is 79.5m OD for the proposed Solar Farm Development.

The flood Inundation map from the 100 year and 1000 year Flood Simulations is presented in Figure 21. The flooding shown within the Solar Farm Sites outside of the drains is pluvial ponding. This will be completely eliminated by the proposed solar farm internal drainage system which is designed to collect and discharge rainwater from the bog surface at the Solar sites to the adjacent longitudinal drains.

A comparison between existing and proposed computed maximum flood levels for both 100 year and 1000 year events is presented in Figures 20 and 21 which show a flood level reduction at the Solar Farm sites and an increase in flood level in central section of the Bog under the proposed drainage case (note in Figures 20 and 21 blues represent a reduction and greens to yellows represent an increase).

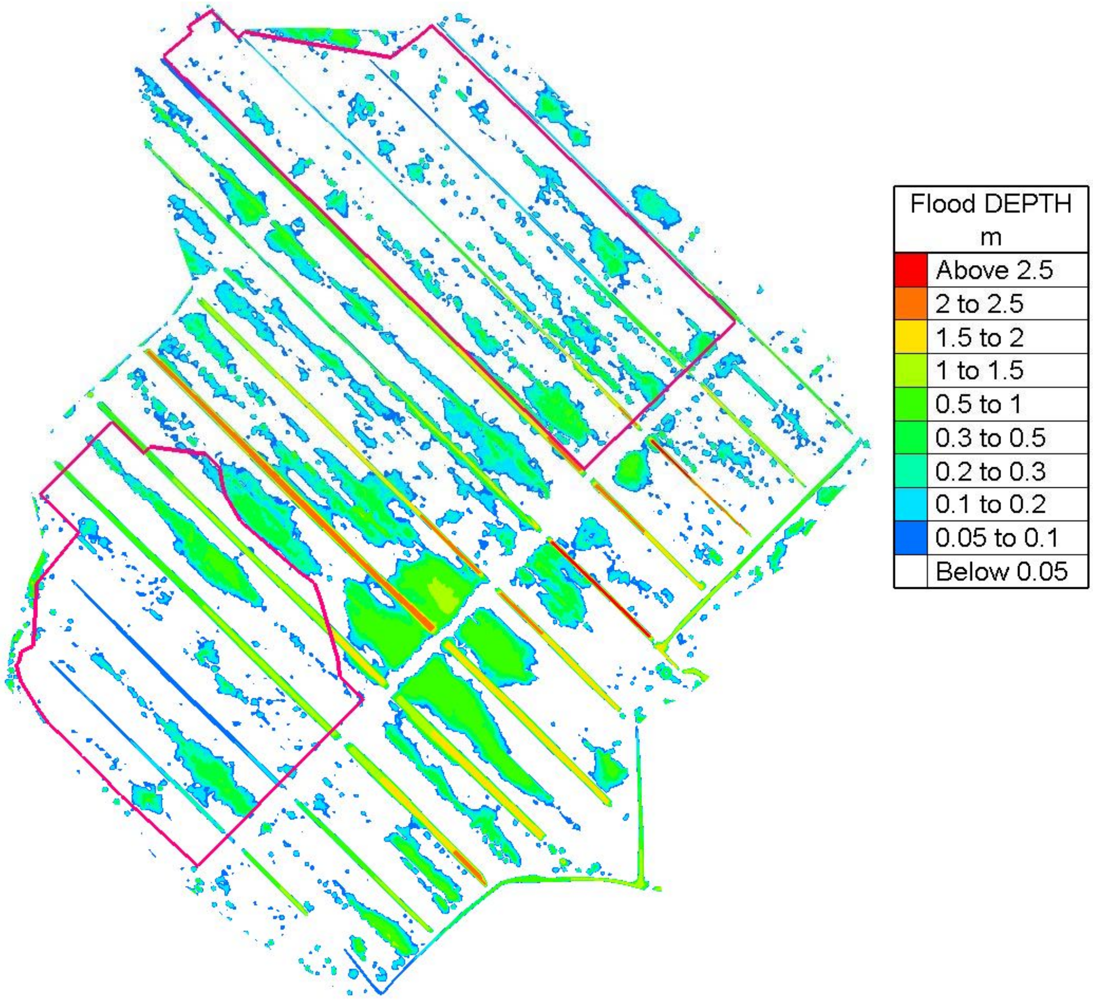

Figure 19 Computed Water Depths at 100year Event – Proposed Development Case

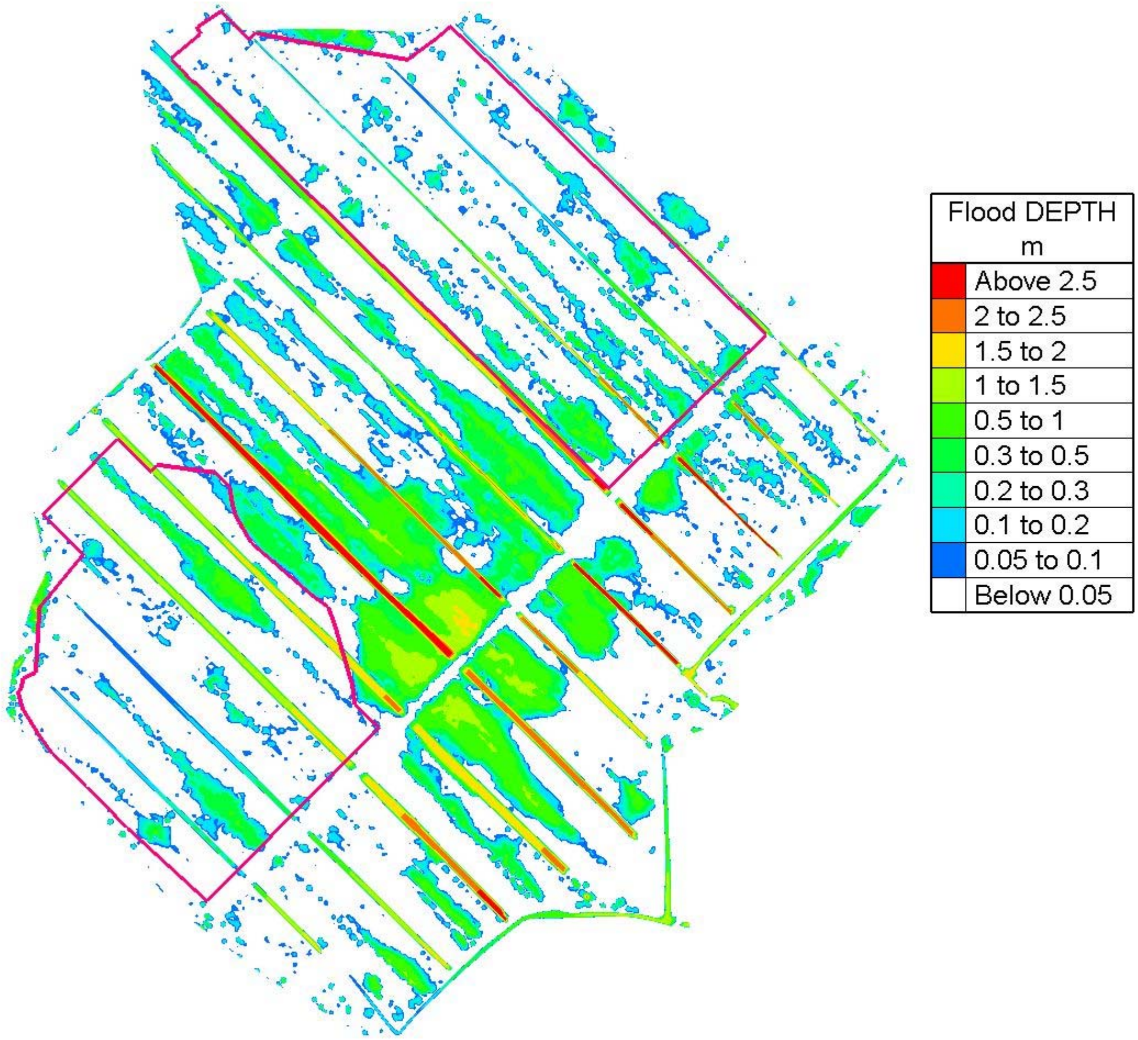

Figure 20 Computed Water Depths at 1000year Event – Proposed Development Case

Table 11 Computed Return Period Flood Levels in longitudinal drains upstream of disused rail line track for Proposed Development Case

Reference	100year max Flood Level m OD	1000year max Flood Level m OD	1000year max Flood Level with 30% CC m OD
Drain 1	79.07	79.45	79.58
Drain 2	78.87	79.13	79.32
Drain 3	78.74	79.11	79.30
Drain 4	78.73	79.11	79.29
Drain 5	78.73	79.10	79.29
Drain 6	78.73	79.10	79.29
Drain 7	78.73	79.09	79.29
Drain 8	78.74	79.11	79.30
Drain 9	78.74	79.13	79.32
Drain 10	78.77	79.15	79.34
Drain 11	78.78	79.16	79.36

Note green shading indicates drains traversing through Solar Farm Development site areas

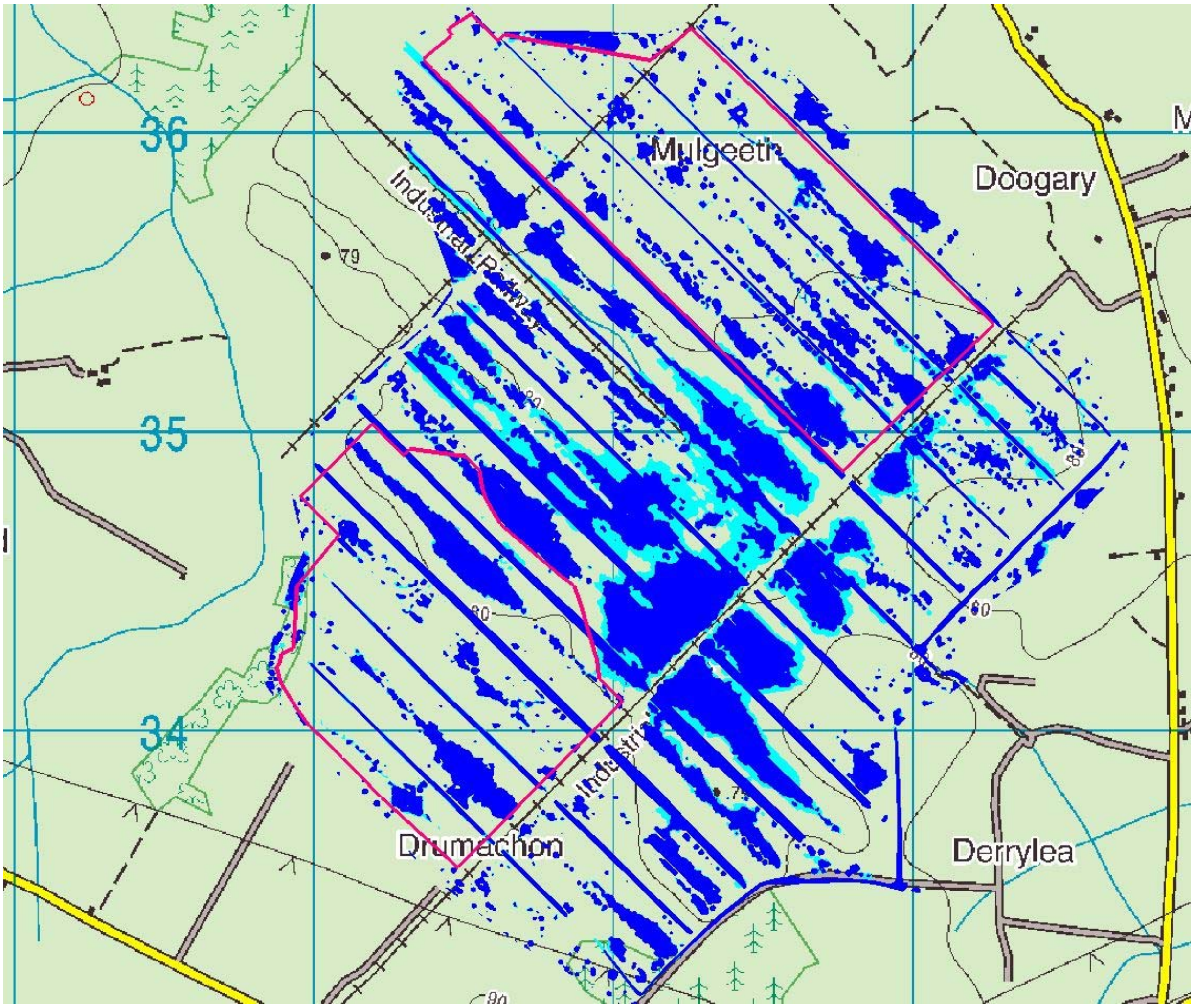

Figure 21 Flood Risk zones for proposed managed site with proposed drainage and flood flow management (Blue – Flood Zone A, Cyan Flood Zone B and and transparent Flood Zone C).

(Note The proposed solar site drainage system will eliminate pluvial ponding within the solar Farm sites with the Flood Risk area within the solar sites only associated with the drainage channels).

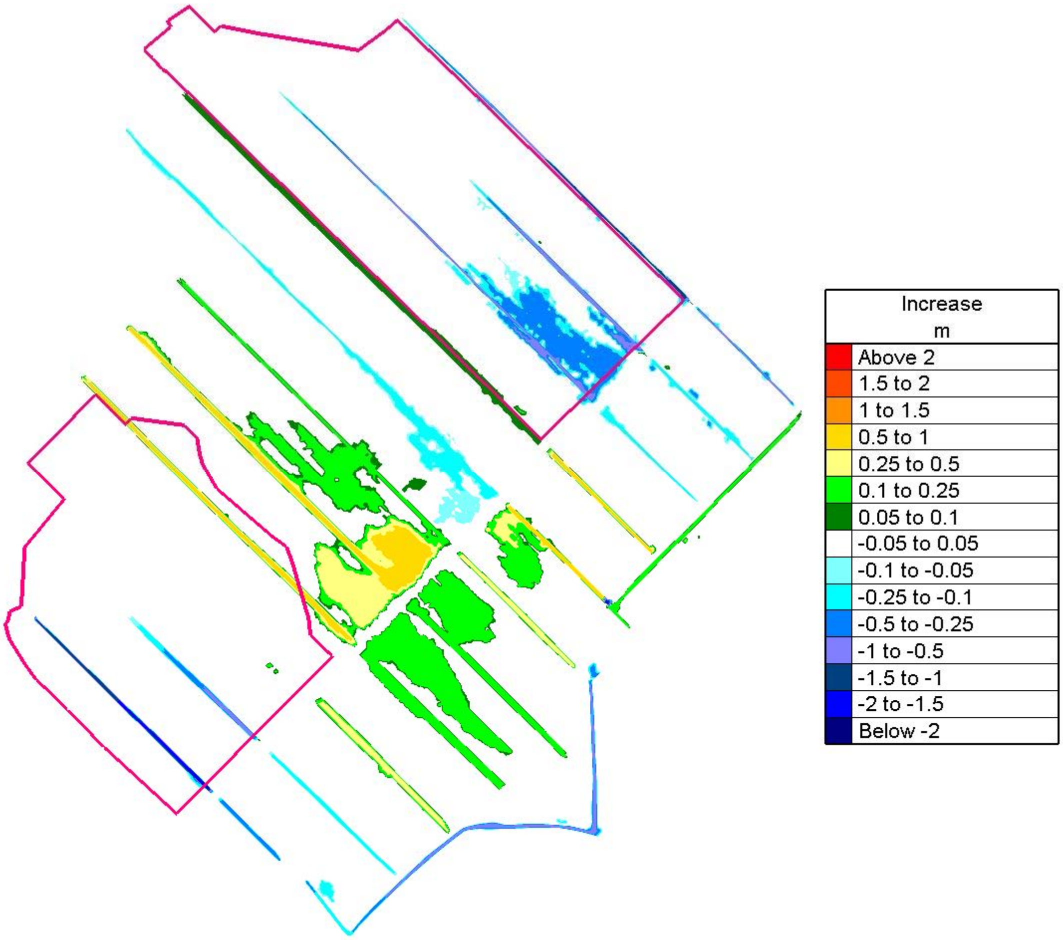

Figure 22 Comparison in predicted peak Flood levels between Existing and proposed cases under the 100 year Flood Event

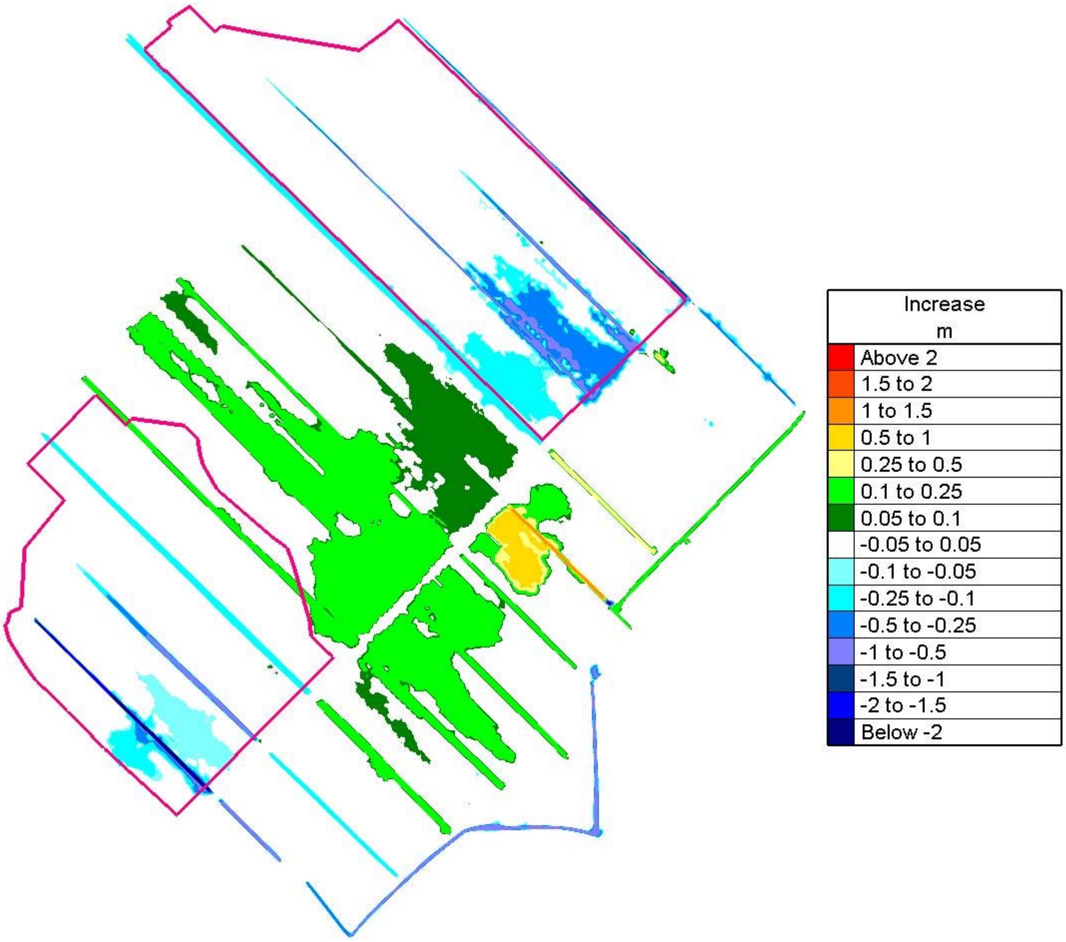

Figure 23 Comparison in predicted peak Flood levels between Existing and proposed cases under the 1000 year Flood Event

For Flood Risk Management on the site it is recommended that the solar panels, access roads/tracks should be placed above a minimum design flood level of 79.5m OD, the compound, parking and peat repository areas be elevated above a level of 80m OD (design level plus freeboard allowance of 0.5m) and the critical infrastructure that includes the inverters and the substation be set above 80.5mOD malin which provides for suitable freeboard in excess of 1m above the design flood level.

5.6 Justification Test in Development Management

The proposed development is located within Flood Zones A, B and C as per Flood Zoning map of the undrained existing bog presented in Figure 16.

The source of flooding is from direct rainwater falling on the site and is generally pluvial in origin and from its subsequent collection and drainage from the bog via large longitudinal drains at 250m centres. Fluvial flooding from upstream catchments is not a source of food risk to the proposed solar sites.

A Justification test in Development Management is required as per Box 5.1 of the Flood Risk Management Planning Guidelines (Nov 2009).

The proposed development is a large commercial Solar Farm which has elements of highly vulnerable and less vulnerable development in respect to flooding. The only elements of the development that would be considered of high vulnerability are the ESB Substation and the Inverters.

The proposed site and adjacent lands are located within a former commercial bog at Timahoe North which is managed by Bord Na Mona. Therefore, the proposed commercial use is reasonably compatible with its former commercial use as a peat harvesting site for such development.

The two solar development sites (NE and SW sites) within the BNM Timahoe North Bog have been selected on generally higher drier ground so as to avoid the lower-lying , more flood prone areas of the bog which are associated with the central section of the bog, refer to Figure 3 and 14.

An engineered drainage scheme is proposed for the Timahoe North bog sites which reduces substantially the potential flood risk to the solar farm development in respect to residual flood risk associated with potential blockages to existing small diameter pipe culverts.

Flood Risk Management measures for the development are as follows:

- The Solar panels to be raised in flood prone areas above the existing ground and set at a minimum level of 79.5m OD which is equivalent to the 1000 year with Climate Change managed flood level.

- The proposed access tracks within the solar sites for maintenance will follow existing ground levels and in certain locations can be allowed to occasionally flood.

- The peat repository areas, site compound and car parking areas will be set and protected against the 1000 year with Climate Change flood level plus 500 mm freeboard which will protect human beings and prevent pollution. The main vehicular access road to the site will be upgraded / constructed to achieve a minimum road level above the 1000 year flood level plus 500 mm freeboard (80mOD).

- The ESB Substation and the Inverters will be set with a minimum finish level of 80.5m OD which protects against the 1000 year flood event with climate change allowance (30% increase in Rainfall intensity) plus 1m freeboard for uncertainty.

The drainage from the site will be attenuated and stored within the Timahoe North Bog land central area below the 79.1 m OD contour level (at 1000 year return period) and throttled by 900mm diameter outlet culvert located on drain 7. The maximum flood discharge rate for the proposed case is less than the existing case and therefore mitigates potential downstream flood impacts.

The proposed development including the Flood Risk Management measures will not cause unacceptable flood impact to other third-party lands.

Management of Flood Risk on the site for the proposed development can be carried out not to impact significantly on the ecology of the Timahoe North Bog. This is achieved through including check-dams/ invert levels in the Longitudinal drains to maintain normal water levels in these drains above the disused rail line track at 78m OD Malin.

Vehicular Access to the essential infrastructure elements of the development i.e. the site control offices and the ESB Substation is flood proofed against the 1000 year flood level plus freeboard.

Residual Flood Risk to the development can be minimised through active management of the drainage infrastructure on the site including provision of large maintained transverse collector drain, large box culvert replacing existing pipe culvert under the disused rail line track and a managed flow control facility with high level overflow at the Timahoe North outlet point.

6. Conclusions

A detailed site specific Stage 3 Flood Risk Assessment of the Timahoe North Solar Farm Development was carried out in accordance with the Flood Risk Management Planning Guidelines (2009).

The Flood Risk Assessment shows that the proposed solar sites on the existing Bord Na Mona Bog at Timahoe North are on lands subject to potential flooding. The flood risk categories for these lands varies from Flood Zone A to C. The source of flooding is from direct rainwater falling on the bog and from its subsequent collection and drainage from the bog via large longitudinal drains running at 250m centres, orientated NW to SE which empty to an existing perimeter collector drain at the southeast end, discharging via small and potentially blockage prone pipe culverts. Therefore, the source of flood risk is generally pluvial in origin.

The two solar development sites (NE and SW sites) within the BNM Timahoe North Bog have been selected on generally higher drier ground so as to avoid the lower-lying flood prone areas of the bog which are associated with the lower central section of the bog, refer to Figure 3.

Fluvial Flooding from upstream catchments is not a source of food risk to the proposed solar sites.

The Flood Risk Assessment showed that development of these sites is justifiable under the Flood Risk Management Planning Guidelines Justification Test Box 5.1 – Development Management.

A proposed drainage scheme for the site was developed and shown to suitably mitigate flood risk on the site both potential and residual Flood Risk without impacting the flood risk to adjacent and downstream Third Party lands.

Residual Flood Risk to the development can be minimised through active management of the proposed drainage infrastructure on the site.

The proposed development is considered sustainable and flood management measures designed to cater for recommended future climate change allowances. Management of Flood Risk on the site for the proposed development can be carried out not to cause unacceptable impact on the ecology of the Timahoe North Bog.

The Flood Risk Assessment showed that development of these sites is justifiable under the Flood Risk Management Planning Guidelines Justification Test Box 5.1 – Development Management.

7. References

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