IMP/001/012 – Code of Practice for Flood Mitigation at Operational Premises

1. Purpose

The purpose of this document is to provide guidance on the process of establishing the risk of flooding at operational premises within Northern Powergrid and guidance on the appropriate level of mitigation to be applied based on a cost benefit assessment.

This code of practice contributes towards the company's (Northern Powergrid) obligations under The Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002, regulation 3(1)(b) and the Energy Networks Association (ENA) Engineering Technical Report (ETR) 138 – Resilience to Flooding of Grid and Primary Substations. ESQCR regulation 3(1)(b) requires the company to prevent interruptions of supply so far as reasonably practicable and ETR 138 presents a risk based methodology on how to improve the resilience of electricity substations to flooding.

This document supersedes the following documents, all copies of which should be destroyed.

Ref	Version	Date	Title
IMP/001/012	2.0	Mar 2012	Policy for Flood Mitigation at Substation Sites

All amendments are detailed in Section 4.3 – Amendments from Previous Version.

2. Scope

This document applies to all ground mounted operational substation premises in Northern Powergrid. Those premises being distribution substations, primary substations, supply points and grid supply points in the Northeast and Yorkshire licence areas. For the purpose of this code of practice a 'major substation' is defined as any primary, supply or grid type substation, see section 5 Definitions.

This document addresses flooding from tidal (sea) and fluvial (river). Information on surface and groundwater flooding requires further development before the principles outlined in this document can be applied and this COP will be reviewed when further information from the Environment Agency and Local Authorities becomes available.

This code of practice provides guidance on our interpretation of ETR138 and includes an overview of establishing the flood likelihood and impact at a substation, a methodology for carrying out cost/benefit assessment and the flood mitigation measures that may be employed.

This document does not cover non-operational premises under the ownership or control of the company.

2.1 Scope

3. Code of Practice for Flood Mitigation at Operational Premises

3.1 Assessment of Relevant Drivers

This code of practice will make a positive contribution to the following business values:

- Regulatory Integrity;
- Financial Strength; and
- Customer Service.

A significant flooding event at a substation site has the potential to cause damage to company owned property and to cause significant disruption to customers' supplies. The Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002, regulation 3(1)(b) requires the company to prevent interruptions of supply, so far as reasonably practicable.

In November 2000, major flooding in the Yorkshire operational area directly affected 8 major substations to varying degrees. One of these sites, Osgodby Supply Point, had to be taken out of service for some 6 months whilst major rectification works were carried out. The total cost of rectification work at this one site was £1.25m, and additional costs were incurred for the use of mobile generators connected to the local network and for the use of local company generation, with the final cost of recovery from this incident was approximately £4.0m.

In summer 2007 major flooding again caused widespread and sustained power interruptions across the Yorkshire operating area. Supplies to around 130,000 customers were interrupted and flooding occurred at 4 of Northern Powergrid's major substations with substantial damage occurring at 55 Yorkshire secondary substations. Around 110 HV faults and 536 LV faults were recorded where we would normally expect around 14 HV and 80 LV faults over a similar period of time. The company's Gelderd Road control centre in Leeds had to be evacuated and the National Grid, Grid Supply Point (GSP) at Neepsend was flooded and ceased to provide an in-feed to Yorkshire's distribution network which resulted in rota disconnection being implemented. The final cost of recovery from this incident was approximately £6m with the highest cost to restore an EHV substation being approximately £150,000 for Rawmarsh Road.

During August 2007, the government commissioned a review of the flood-related emergencies which occurred during summer 2007. Two reports were published, an interim and final report, entitled 'Learning lessons from the 2007 floods' (also known as the 'Pitt Report' as Sir Michael Pitt was tasked with conducting the review). The reports contain a series of recommendations, with the main area affecting the company being a recommendation to develop a systematic programme which would introduce defined standards on reducing the known risk to critical infrastructure and mandatory business continuity plans.

In response to the serious incidents of flooding in the South Midlands and Yorkshire regions during summer 2007 and considering the findings of the Pitt Report, an industry wide task group was established and facilitated by the Energy Networks Association to develop an Engineering Technical Report (ETR) 138 on flooding. The purpose was to develop a risk based methodology that provides guidance on how to improve the resilience of electricity substations to flooding. The ETR describes the systematic approach to flood risk assessments and protection and prescribes levels of acceptable flood risk.

The company predominately "self-insures" for incidents that cause loss on the distribution system. This means that our owners, Berkshire Hathaway, face an increased liability from events of this type. The floods of 2000 and 2007 did not lead to widespread public criticism of either company, due to the public perception of the "one-off" nature of these events and the limited impact of widespread power cuts. This may not be the case if these incidents were repeated. We are particularly at risk of criticism where we now have knowledge of the sites that flood and an ETR which provides guidance but have taken no action to remedy the situation. Therefore, taking no action is not considered an option.

Berkshire Hathaway has instigated a set of 'Critical Property Unit (CPU) assessments' as part of the overall risk management process. Within the company, critical properties have been defined as operational sites whose loss would cost over £500,000 including Guaranteed Standards payments, remedial expenditure etc. This effectively encompasses all substations where the incoming voltage is greater than 20kV. The CPU assessment of major substations includes the consideration of flood risk in determining the overall risk rating of a specific substation. This process is designed to reduce the financial risk exposure of the company through the implementation of risk mitigation measures for hazards such as flooding.

3.2 Key Requirements

The objectives of this code of practice are:

- To define the generic risk assessment process to enable the risk of flooding at a specific substation location to be determined;
- To provide guidance on a cost/benefit assessment;
- To define the approach that determines whether flood defences are to be implemented at existing or new substation sites;
- To provide guidance on the range of measures that can be adopted to mitigate against the risk of flooding for existing and new substation sites including those that form part of a customer's new development; and
- To provide a single point source of information relating to the application of flood defences for the population of ground mounted substation assets within the company.

3.3 Flood Risk Assessment

This code of practice refers to the 'floodplain' which is defined by the Environment Agency as 'the area that would naturally be affected by flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas'. The floodplain is split into two different areas. These are:

- The area that could be affected by flooding, either from rivers or the sea, if there were no flood defences. This area could be flooded:
  - from the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year, or
  - from a river by a flood that has a 1% (1 in 100) or greater chance of happening each year.
- The additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to a 0.1% (1 in 1000) chance of occurring each year.

These two areas show the extent of the natural floodplain if there were no flood defences or certain other man-made structures and channel improvements.

Ideally mitigation measures proposed within this document should be designed to protect against the 1 in 100 (river) or 1 in 200 (sea) for primary substations and 1 in 1000 floods for grid supply points as appropriate to the practical limitations of the site and the outcome of the cost benefit assessment.

To establish whether a specific location (that may be an existing or proposed substation premises) is at risk from flooding and the potential scale of a flood event, the following guidance is provided. A 'process map' showing the steps of this procedure is provided in Appendix I of this document. This approach to flood risk assessment should be utilised for major substation sites.

3.3.1 Does the location lie within the indicative floodplain?

To establish for a small sample of sites, whether the location in question lies within the floodplain, the postal code of the location (or nearby location) should be entered into the required field on the flood map page of the Environment Agency internet site, http://watermaps.environment-agency.gov.uk.

This will provide an overview of the flood map in the area of interest and help to determine whether the site is located within the floodplain.

It should be noted that this analysis will provide a general indication of whether the location lies within the floodplain. If the analysis provides an uncertain result e.g. if the location appears to be on the periphery of the floodplain, it should be assumed that the substation could be affected by flooding and the assessment should be progressed to the next stage.

It also should be noted that new substation buildings should be built to have a minimum floor level of 750mm above the existing ground level whether or not they are at risk of flooding. This builds in a level of defence against flooding and designs out cable basements.

To establish for many sites, whether the locations in question lie within a floodplain, Information Management should be requested to assist by mapping site grid references against floodplain maps thereby providing a list of all major substations located in the floodplain.

Floodplain maps are published by the Environment Agency every quarter and are subject to change. Therefore all our major substations should be mapped against the floodplain maps at least on an annual basis. System Strategy will be responsible for ensuring that the data is updated, however when the work programme investment appraisal document is reviewed, usually biennially, the author will initiate the update and request that Information Management assist. AMP2VIEW should be updated with any new data as and when it becomes available.

3.3.2 What is the probability of flooding at the location?

If the location of the site is shown to lie within the extent of the floodplain through the Environment Agency website inquiry, it will be located within either the 1 in 100 year and 1 in 200 year floodplain (dark blue area) or 1 in 1000 year floodplain (light blue area).

Primary substations located within the 1 in 100 or 1 in 200 year floodplain should be progressed through the assessment process however primary substations located within the 1 in 1000 year floodplain will not be considered for flood mitigation and should therefore not be progressed through the assessment process.

Supply points and grid supply points should be progressed to the next stage of the assessment process if they are located on the 1 in 100, 1 in 200 or 1 in 1000 year floodplain.

3.3.3 What is the potential height of the flood?

For primary substations the 1 in 100 or 1 in 200 year flood height must be established for the location in question. For supply points and grid supply points the 1 in 100 or 1 in 200 and 1 in 1000 year flood heights must be established. This information may have been determined already and if so it will be available on AMP2VIEW under the “Site Inspections” section and the initial action should be to check if this information is held on AMP2VIEW. If it is not available on AMP2VIEW then a request should be made to the Environment Agency using the pro-forma in Appendix II. If the information is not available from the EA, a specialist service provider should be employed by the company to carry out a Flood Risk Assessment in accordance with the Flood Estimation Handbook to establish the flood heights for the relevant return periods except in the case of customer specific new substations, where the developer shall be responsible for carrying out a flood risk assessment which should be made available to the company along with the proposed flood mitigation measures for the respective development. The Flood Estimation Handbook provides guidance on rainfall and river flood frequency estimation in the UK.

This information should be initiated by the System Design Engineer for new substations, asset replacement or reinforcement if necessary and for works associated with work programme 69 the responsible officer should initiate the information request. AMP2VIEW should be updated with any new data as and when it becomes available.

Based on advice provided by EA and in line with ETR 138, the potential flood height should be increased for by the following amounts:

- Fluvial flooding

By 20% total to allow for climate change impacts during the lifetime of the assets.

- Sea Level

Increase by the corresponding amount in the table for climate change impact for the lifetime of the assets, nominally 60 years.

Region	Net sea level rise (mm/yr)			
	1990- 2025	*2025- 2055*	*2055- 2085*	*2085- 2115*
Yorkshire	4.0	8.5	12.0	15.0
Northeast	2.5	7.0	10.0	13.0

- Freeboard

Add 300mm after an allowance for climate change has been made to allow for uncertainties in data and modelling.

3.3.4 What is the height of the critical equipment above sea level?

The Above Ordnance Datum (AOD) level for the lowest critical equipment at the substation under assessment should be established. This is a measure of the height of the equipment above sea level.

Critical equipment could include:

Batteries, bus wiring, compressors and air systems, bus bars, relays, fuses, metering, NER or NEX, polymeric components, secondary wiring, switchgear bushings, secondary wiring termination boxes and transformer breathers.

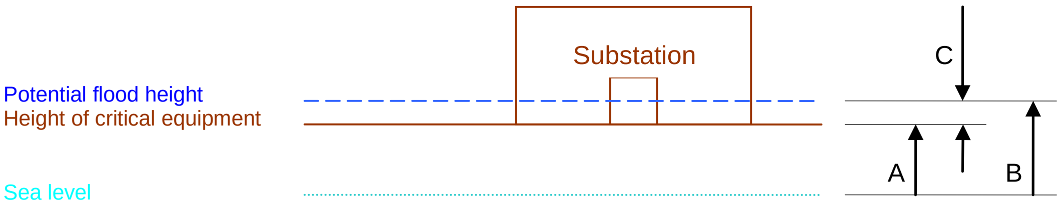
This information should be requested via the appropriate project engineer who may utilise an external service provider to attend the site and establish either the floor level of the substation compound or the level of the critical equipment using appropriate equipment such as a Global Positioning Satellite (GPS) system. If the floor level is established then the height of the critical equipment above (or below) this level will then need to be determined.

An existing (or proposed) substation site that lies within the floodplain may be located on land that is elevated above the potential flood height. In such cases the site will be considered to be naturally protected against the effects of a potential flood if it is higher than the flood height. In such cases the location need not be considered further for flood mitigation measures.

3.3.5 Is the substation at risk of flooding?

A comparison of the potential flood height and the height of the critical equipment can be made.

For primary substations the potential flood height of either the 1 in 100 or 1 in 200 year flood should be compared against the height of the critical equipment. For grid supply points and supply points either the 1 in 100 or 1 in 200 and the 1 in 1000 year flood height should be compared against the height of the critical equipment. The following diagram provides guidance in determining the flood risk for a specific set of data.



A = the height of the critical equipment above sea level (mAOD)

B = the height of the potential flood above sea level (mAOD)

C = flood depth - the height of the potential flood level with respect to the critical equipment level (B-A) (m)

If the substation is found to be naturally protected against the effects of a potential flood i.e. flood depth is less than or equal to zero, it need not be considered further for flood mitigation measures. It should be noted that new substation buildings should have a minimum floor level of 750mm above the existing ground level whether or not they are at risk of flooding. This builds in a level of defence against flooding and designs out cable basements.

3.4 Existing or Proposed Public Flood Defences

Before deciding to develop site specific flood defences the Environment Agency should be contacted to establish the existence, type, condition and height of any existing public flood defences. These questions are included in the pro-forma in Appendix II. In addition, the Environmental Agency should be contacted to establish if there are any proposed flood defences or if there is a case for public authorities to provide protection.

If flood defences are in existence or proposed, then the company may not need to install site specific flood defences if the following conditions are met:

- The flood defence provides or will provide resilience to a 1 in 100 or 1 in 200 year for primary substations and 1 in 1000 year for grid supply points and supply points; or
- The flood defence provides a greater degree of resilience than could be justified through the cost benefit assessment; and
- The defence is in good condition; and
- The flood defence is subject to ongoing maintenance.

Otherwise the site should be subject to the following assessment.

3.5 Flood Defence Measures

The flood defence measures required at a substation location will depend on the site specific conditions, the potential flood depth and whether they are to be applied to a new or existing substation.

A generic range of flood defence options are detailed in the following sections and the determination of the specific solution shall be the responsibility of the designer of that scheme.

3.5.1 Major Substations

The application of flood defences at major substation sites will be dependant on their current status. This would fall into the following categories:

- An existing substation site with no major refurbishment or rebuild work intended in the next ten years.
- An existing substation is subject to major refurbishment work in short to medium term (0 to 10 years) investment schedule.
- A planned new substation development.

3.5.1.1 Cost Benefit Assessment

If the cost of the mitigation per MWh lost (associated with the loss of the substation in question) is less than or equal to £1000[1] then the mitigation may proceed. An alternative way of viewing this is that the cost for mitigation that can be justified without further assessment is 1000 multiplied by the MWh lost. As a guide, the average MWh over 1 week (7 days) is considered to be a reasonable approach for determining the MWh lost as it is thought that a typical event may result in 1 week's lost MWh. Appendix III provides further information on how this threshold has been reached and there is a worked example in a separate excel spreadsheet, 'IMP/001/012 Worked Example'.

If the cost of the mitigation per MWh lost is more than £1000 then critical infrastructure should also be considered. Critical infrastructure comprises those sectors which supply essential services to the citizen on which normal daily life in the UK depends and where the loss of such services could lead to a worst case such as mass evacuation. The use of the "V" list of the Electricity Supply Emergency Code (ESEC) should be used initially to identify such customers which include:

- coal mines;
- major airports and control facilities;

[1] A pragmatic approach has been taken to determine the threshold cost of mitigation per MWh lost based on assessing historic flood mitigation schemes.

- railway operations;
- gas sites;
- licensed electricity generators;
- essential water and sewerage installations;
- hospitals;
- ports and docks;
- postal telecommunications and broadcasting services; and
- oil refineries and vital oil pipeline pumping stations.

In addition to using the "V" list, enquiries to Control Operations and Emergency Planning may also be made to identify such customers. If critical infrastructure is identified, a weighting of 100 should be applied to their MWh lost and this should then be added to the total MWh lost for the site and used to re-calculate the cost of the mitigation per MWh lost. If this reduces the cost of the mitigation per MWh lost to less than or equal to £1000 then the flood mitigation may proceed.

If the cost of flood mitigation per MWh remains greater than £1000 then the level of resilience will be reduced until the cost of mitigation per MWh is £1000 or less. For example, the height of the flood defence may be reduced so that instead of providing resilience to a 1 in 1000 year flood for example, the resilience may be reduced to a 1 in 100 year flood or less.

3.5.1.2 Existing Major Sites with No Planned Asset Replacement

For existing major substation sites where there are no schemes identified in the capital investment plan for substantial asset replacement work (such as site refurbishment including switchgear, transformer and building replacement), it is not expected that any significant alterations will be made to electrical equipment or buildings. For such cases, one of the following options may be adopted and be considered bearing in mind the cost benefit assessment of the design.

1. Construction of a subterranean "wall" around the perimeter of the substation site (including compound and buildings, extending above ground (e.g. concrete, sheet piling). The defences shall normally be hard construction. The installation shall normally consist of flood gates that will allow access to the substation but will provide protection against flood water when required. This option shall also provide a permanent ground water sump and intelligent pump that discharges to the outside of the flood wall. It should be noted that this system does not provide a waterproof 'tank' around the substation as ground water will rise inside the flood wall. During a flood event the operation of the water pumps is essential to control this ground water rise and therefore the operation and effectiveness of the pumps should be maintained and monitored on site with additional portable pumps available should a failure occur if it is considered operationally safe to do so.

2. Construction of a waterproof wall within the site to protect critical assets. This option may be adopted where only specific assets are at risk and may be used in conjunction with option 3.

3. Any of the following measures may be used where the flood height is not significant, i.e. usually 300mm or less:

- Installation of flood protection to door openings;
- Raising ventilation holes;
- Raising walls; and
- Sealing cable troughs.

4. Deployment of a temporary flood barrier around the perimeter of the substation site (or specific assets). This type of equipment can be utilised where a permanent flood defence is compromised due to damage or has been partially decommissioned during substation refurbishment work. Additionally, this type of equipment can be utilised at substations where permanent defences cannot be justified from the cost benefit assessment. Such systems can be deployed in real time MIMP

in the event of a flood warning for a particular location. Plans of substations sites indicating how the temporary flood barriers can be deployed have been developed for relevant sites. Appendix IV presents a list of these sites and an example of the plan.

Ideally mitigation measures should be designed to protect against the 1 in 100 (river) or 1 in 200 (sea) for primary substations and 1 in 1000 floods for grid supply points as appropriate to the practical limitations of the site and the outcome of the cost benefit assessment. Local council flood development plans should be consulted to check that our mitigation plan considers their guidance.

3.5.1.3 Existing Major Sites with Planned Asset Replacement

For existing major substation sites where there are plans for substantial asset replacement work (such as site refurbishment including switchgear, transformer and building replacement), the following options should be considered in addition to those described in section 3.5.1.2:

1. Where all assets at the substation are to be replaced, raising the floor level of the substation above the potential flood height may be considered. This may entail the importing of material to raise the ground level of the site or through the construction of the substation building with the floor level above ground level. Additional land may need to be acquired together with means of access.

2. Where only partial asset replacement is planned, consideration may be given to raising the particular assets above the flood height at the time of replacement in addition to the main site defence.

3. Relocation of the substation to a location outside the flood risk area (one that is elevated above the potential flood height) may also be considered. This could be another part of the existing site and it should provide adequate protection.

Again, mitigation measures proposed within this document should be designed to protect against the 1 in 100 (river) or 1 in 200 (sea) for primary substations and 1 in 1000 floods for grid supply points as appropriate to the practical limitations of the site and the outcome of the cost benefit assessment. Local council flood development plans should be consulted to check that our mitigation plan considers their guidance.

3.5.1.4 New Major Sites

For new major sites the key requirement will be that the company's exposure to flood risk is not increased by the connection of a new substation. Preference should always be given to locating a new substation outside of the floodplain or at a location that is elevated above the potential flood height. Where this is not feasible the substation design should be such that the floor level of the substation is raised above the potential flood height as per option 1 in section 3.5.1.3. Local council flood development plans should be consulted to check that our design considers their guidance.

3.5.2 Distribution Substations

3.5.2.1 Existing Distribution Substation Sites

In general existing distribution substations (indoor) on the network will not be flood defended. However, if a requirement is identified for a specific substation e.g. where a substation has been previously affected by a flood event or a substation that feeds a critical pumping station or critical infrastructure, the following flood mitigation measure may be undertaken:

- Installing flood protection to door openings (indoor substations);
- Raising ventilation holes above the potential flood height;
- Sealing cable entry positions;
- Installing automatic pumping equipment, and
- Installing electrical apparatus at an elevated level to protect it from damage.

The decision as to what flood mitigation measures to undertake will depend on an assessment of the individual substation but may take into consideration the flood depth and the height of the critical equipment which will be dependent on the type of switchgear.

3.5.2.2 New and Replacement Distribution Substation Sites

Where a substation has been identified for asset replacement, an assessment of the flood risk shall be undertaken. Should this analysis result in the substation being identified as being at risk, the substation should be built at an elevated level. Standard designs have been developed for indoor distribution substations elevated at 600mm and 1200mm above ground level. These designs are available in code of practice IMP/003/001 - Construction and Building Design of Ground Mounted Secondary Substations.

The relevant standard design should be selected based on the potential flood height.

3.5.2.3 New Substations Forming Part of a Customer's Development

Where a new substation is to be installed as part of a customer's development and it is at risk of flooding, the substation shall be designed to be protected against the potential flood depth. The developer shall be responsible for carrying out a flood risk assessment and it should be made available to the company along with the proposed flood mitigation measures for the development. All costs associated with compliance with this policy shall be met by the developer.

In general new substations shall not be located at the basement level of a proposed development unless the developer provides sufficient evidence that the potential flood risk has been mitigated and the substation does not create a confined space.

3.6 Assumptions

This code of practice is aimed at ensuring that all ground mounted operational substation premises in the company are adequately protected against the potential effects of flooding events. The effective application of this code of practice will contribute to minimising damage caused to the substation population in the event of a flood.

The following assumptions have been made and will be required to ensure the effective delivery of this code of practice into the business:

- The current exposure of the company to financial risk remains valid with respect to uninsured financial losses on our distribution network.
- A suite of standard designs are available for flood defended ground mounted distribution substations to enable appropriate engineers to either adopt a standard flood defended design or modify such a design as required by the specific project.
- A programme of work is authorised to provide flood mitigation measures at existing major substation sites.
- At the time of drafting this document, the data utilised in its production was the most up to date information available with which to formulate the requirements of this code of practice.
- When additional information is made available by the Environment Agency and local authorities on surface water flooding, this code of practice will be reviewed.
- ETR 138 remains the industry guidance.

4. References

4.1 External Documentation

Reference	Title	Version and date
ESQCR	The Electricity Supply, Quality and Continuity Regulations 2002.	2002/2665
ETR 138	Resilience to Flooding of Grid and Primary Substations.	Oct 2009
EA flood map website	http://watermaps.environment-agency.gov.uk.	n/a
ESEC	Electricity Supply Emergency Code ESEC	Jan 2005
Flood Estimation Handbook	Flood Estimation Handbook, Wallingford Hydrosolutions Ltd.	2008

4.2 Internal Documentation

Reference	Title	Version and date
IMP/003/001	Construction and Building Design of Ground Mounted Secondary Substations.	1
Worked example	'IMP/001/012 Worked Example'.	n/a

4.3 Amendments from Previous Version

Reference	Amendment
Whole Document	Document re-formatted and re-branded.
3.3.1 Does the location lie within the indicative floodplain?	Environment Agency flood map internet address updated.
3.7 Implementation and Monitoring	Section removed.
3.8 Planned Review	Section removed.
3.9 Superseded Documentation	Section moved to section 1.
6.0 Authority for Issue	Table added for the review period proposal.

5. Definitions

Term	Definition
Distribution substation	A substation containing equipment operating at a primary voltage of 20kV or below.
Primary substation	A substation containing equipment operating at a primary voltage of 66kV or 33kV.
Bulk Supply point	A substation containing equipment operating at a primary voltage of 132kV.
Grid Supply point	A substation containing equipment operating at a primary voltage of 275kV or 400kV.
Major substation	Any primary substation, supply point or grid supply point.
LV	Low voltage.
HV	High voltage.
EHV	Extra high voltage.
MWh	Megawatt hour.
MIMP	Major Incident Management Plan.
AMP2VIEW	Asset register viewer.
"V" list	Protected customer list.

6. Authority for issue

6.1 CDS Assurance

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

		Sign	Date
Sarah Phillips	CDS Administrator	Sarah Phillips	11/12/14

6.2 Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

Review Period - This document should be reviewed within the following time period.

Standard CDS review of 3 years	Non Standard Review Period & Reason	
Yes	Period:	Reason:

		Sign	Date
Paul Hollowood	Policy & Standards Engineer	Paul Hollowood	11/12/14

6.3 Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

		Sign	Date
Chris Holdsworth	Policy & Standards Manager	Chris Holdsworth	11/12/14
Dave Sillito	Primary Engineering Projects Manager	David Sillito	23/02/15
Phil Groves	Investment Planning & Delivery Manager	Phil Groves	24/12/14
Paul Buttery	Building and Civil Manager	Paul Buttery	15/12/14

6.4 Approval

Approval is given for the content of this document.

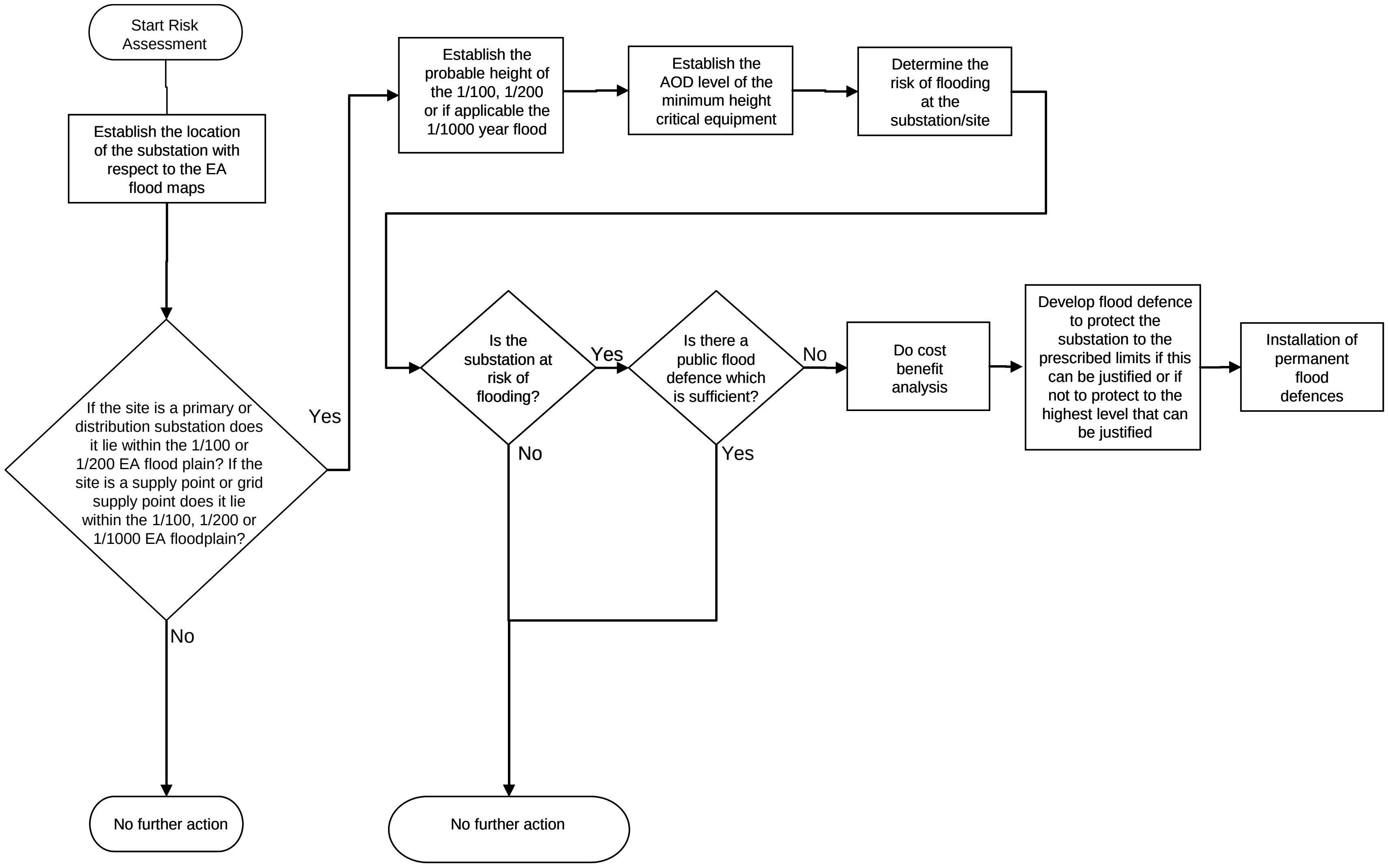
		Sign	Date
Mark Nicholson	Head of System Strategy	Mark Nicholson	22/12/14

6.5 Authorisation

Authorisation is granted for publication of this document.

		Sign	Date
Mark Drye	Director of Asset Management	Mark Drye	06/03/15

Appendix I – Flood Risk Assessment Process Map



Appendix II – Environment Agency Pro-forma

Flood Risk Assessment information for Electrical Sites Vulnerable to Flooding (England only - can be adapted as necessary for Wales and Scotland).

			EA	EA	EA	EA	EA	EA	EA	EA	EA	EA	EA	EA	EA
								Flood Risk - Flood Zone and potential, maximum water levels on the site.							
Site name	**O.S. grid Reference**	**Is the site in or out of the floodplain?** (IN / OUT)	**Most likely cause of flooding** (Fluvial, Coastal, surface water, other)	**Does the site benefit from a flood defence scheme?** (Y/N)	**Condition of the defences protecting the site** (condition grade 1 to 5)	**Type of defences**	**Height of flood defences (mAOD)**	**Flood Zone 1, 2, 3**	**Potential, maximum flood water level (mAOD) if available #**	**indication of data accuracy**	**Terrain map type used** (SAR / LIDAR)	**Age of Terrain map** (Years or Date)	**Is the site within an EA Flood Warning Area?** (Y / N)	**Flood Warning - approximate notice period that a warning would be issued in advance** (48hrs / 36hrs / 24hrs / 12hrs / 8hrs / none)	**Historical Flooding Information**
Example	xxx-yyy	IN	Fluvial	Y	3			3	1:100 - 62.1m 1:200 - 62.5m, 1:1000 - 62.8m	+/- 25mm	LIDAR	2003	Y	12hrs (8hrs min)	Example flooded to a depth of 62.7mAOD in 2000 from surface and fluvial flood water.

mAOD = meters Above Ordinance Datum. NB: Potential maximum water level should only be supplied from detailed models (those that produce results fit to be used at a site / detailed level). This does not include National Generalised models.
If the EA has no levels available that are fit for detailed site level decision making then the site owner will need to work out flood levels through calculation / modelling to compare against the ground level at the location. The flood level will need to be produced from either an appropriate computer model or from appropriate hand calculations (this will be location dependent to determine whether hand calculations will be of use). The ground level will need to be from an appropriate survey.

Flood Zone	**chance of flooding**
1	the chance of flooding in any one year is less than 0.1% (i.e. a 1000 to 1 chance).
2	the chance of flooding in any one year between 0.1% and 1% fluvial or 0.5% tidal (i.e. between a 1000 to 1 and a 100 to 1 fluvial or 200 to 1 tidal chance).
3	chance of flooding in any one year is greater than or equal to 1% (i.e. a 100 to 1 chance) for river flooding and greater or equal to 0.5% (i.e. a 200 to 1 chance) for coastal and tidal flooding

Appendix III – Workings Related to Cost/Benefit Methodology (as at Mar 2012)

Three methodologies were compared:

- Cost per customer;
- Cost per lost MWh; and
- Ofgem's methodology for assessing the FBPQ allowance for DPCR5.

The cost per customer and cost per lost MWh were calculated for historic flood defence schemes. The cost per lost MWh has been determined by calculating the average MWh distributed over 1 week (7 days) using half hourly data from PI over a period of 1 year. It is thought that 1 week would be a reasonable starting point to assume that the substation would be off supply if it was subjected to flooding.

The cost per customer has two outliers for historic flood defences; Saltend and Snaith. Snaith is an outlier because the cost of the scheme is high because the solution involves relocating the substation and was a special case because it was located on a sacrificial floodplain. Saltend is an outlier because the number of customers is small. When calculating the average cost per customer for schemes submitted in FBPQ, all the schemes were within the threshold.

The cost per MWh lost has one outlier for historic flood defence schemes; Snaith which was a special case as explained above. All other schemes cost less than £1000 per MWh lost. When doing the same analysis for schemes submitted in FBPQ three schemes were greater than £1000 per MWh lost; Doncaster Central, Thorne and Todmordon. Doncaster Central is only marginally above £1000 per MWh and if critical customers are taken into account by multiplying their lost MWh by a weighting factor it is thought that the cost per MWh can be reduced to £1000 per MWh. Todmorden and Thorne both have high flood heights over 5m and 3m respectively which results in the cost for mitigation being high and it is therefore thought reasonable that mitigation to protect them to the 1 in 100 or 1 in 200 year is not considered to be economical and therefore the threshold should be set at £100 per MWh lost.

Ofgem's analysis has been replicated although it has not been possible to replicate it completely as the weighting applied to critical customers can not be established. Ofgem's analysis results in most schemes having expenditure reduced which would have the effect of not being able to mitigate most substations to the aspired level of resilience.

The methodology that seems to provide the most reasonable results is cost per lost MWh with a threshold of £1000, given the vast majority of schemes are within this threshold. To take into account critical infrastructure a weighting should be applied to their lost MWh. The half hourly metering data should be obtained and used to determine the MWh lost for the same period of time. By inspection a weighting of 100 appears to give the most reasonable result; a weighting of 10 doesn't change the answer and 1000 would give too much bearing to the critical infrastructure. The MWh lost for the critical infrastructure should be added to the MWh lost for the site and used to calculate the cost per lost MWh. This has been done for Elland and Moss Road in the table below.

Highlighted cells indicate that the costs exceed the threshold

Historic Flood Defence Schemes						
Site	Actual Cost (£)	No. Customers	Type or flood defence	Level of Protection	Cost/Customer (486 threshold)	Cost/MWh lost (assuming 1 week) (1000 threshold)
SALTEND 132/33KV	£380,000	43	1.2m wall		8837.2	718.3
SNAITH 33/11KV	£2,724,348	3085	Relocation		883.1	28057.1
QUEENS ROAD 33/11KV	£99,600	677	1.2m wall	not on flood plain	147.1	41.2
RAWCLIFFE 66/11KV	£120,000	1848	1.2m wall		64.9	621.8
GREYFRIARS RD 33/11 KV	£80,000	2435	1.2m wall	not on flood plain	32.9	62.8
South Ferriby	£94,000	3387	Mound to raise s/s	1/100	27.8	54.8
IMMINGHAM 132/33KV	£276,000	10541	1.2m wall		26.2	63.6
Spenborough	£175,000	7073	Two storey flood building		24.7	130.3
STANLEY STREET 33/11KV	£83,895	3600	1.2m wall	not on flood plain	23.3	76.3
HULL EAST 33/11KV	£176,400	8119	1.2m wall	not on flood plain	21.7	156.8
OLYMPIA MILLS 33/11KV	£151,200	6987	1.2m wall	not on flood plain	21.6	102.5
FLIXBOROUGH 33/11KV	£94,800	4473	1.2m wall		21.2	65.7
BLACKBURN MEADOWS B 132/33KV	£258,000	12212	1.2m wall		21.1	50.1
THORNE 66/11KV	£162,000	7891	1.2m wall		20.5	109.1
MIRFIELD 33/11KV	£151,000	11273	1.2m wall	approx 1/100 flood protection	13.4	94.1
SNAITH 33/11KV	£37,500	3085	1.2m wall		12.2	386.2
DONCASTER CENTRAL 132/33KV	£217,000	31706	1.2m wall	1/150 flood protection	6.8	321.0
HULL EAST 132/33KV	£219,000	32365	1.2m wall	not on flood plain	6.8	65.5
HULL SOUTH 132/33KV	£213,000	49398	1.2m wall		4.3	22.7
FERRYBRIDGE B	£37,500	12768	1.2m wall	not on flood plain	2.9	1.4
KIRKSTALL C 132/33KV	£186,000	72216	1.2m wall	1/100 flood protection	2.6	20.8
				Average	**486.8**	**1486.8**
				Upper quartile	**32.9**	**62.8**

Proposed Flood Defence Schemes

Site	Cost as Submitted in FBPQ	No. Customers	Number of critical customers supplied by substation	Types of critical customers supplied by substation	Type or flood defence	Level of Protection	Cost/Customer (486 threshold)	Cost/MWh (assuming 1 week) (1000 threshold)	Ofgem allowance (assuming <=£7.4/unit change in risk allowed)	Cost/MWh with critical infrastructure with a rating of 100
Creyke Beck	£200,000	242620	0	0	Rebuilt and raised as part	1000	0.8	4.4	£200,000	
Elland 275/132kV (New) 14	£1,100,000	189467	1	Hospital	wall	1000	5.8	32.8	£1,100,000	22.0
Keadby	£2,560,000	116418	0	0	wall	1000	22.0	63.2	£1,722,986	
Doncaster B 132/66kV 45039	£770,000	89600	0		wall	1000	8.6	313.3	£770,000	
Kirkstall C Section 2 & 5 132/33kV 47347	£814,000	73760	0		wall	1000	11.0	91.2	£814,000	
Thornhill 132/33kV 7296	£289,000	57743	0		wall	1000	5.0	32.9	£289,000	
Holmfield 132/33kV 12	£594,000	56398	0		wall	1000	10.5	655.6	£594,000	
Hull South 132/33kV 5625	£748,000	49321	1	Pumping Station	wall	1000	15.2	79.7	£729,951	
Rodley 132/33kV 1525	£572,000	44356	0		wall	1000	12.9	67.9	£572,000	
Saint Andrews Road	£428,200	37640	0	0	wall	1000	11.4	69.8	£278,536	
Brighouse 132/33kV 2	£550,000	35817	0		wall	1000	15.4	77.5	£550,000	
Bransholme	£620,000	34996	0	0	wall	1000	17.7	296.9	£620,000	
Yarborough Road	£433,200	33193	0	0	wall	1000	13.1	72.2	£433,200	
Saltend 275/132 kV 7859	£682,000	32436	0		wall	1000	21.0	91.0	£480,053	
Hull East 132/33kV	£748,000	32394	1	Pumping Station	wall	1000	23.1	223.6	£479,431	
Doncaster Central 132/33kV 45040	£726,000	30853	1	Railway station	wall	1000	23.5	1074.0	£684,937	
Leeds North 132/33kV 3348	£682,000	26561	2	Pumping Station and waterwor	wall	1000	25.7	139.1	£589,654	
Low Road 132/33kV 999	£442,000	26304	0		wall	1000	16.8	46.5	£442,000	
Wakefield Monckton Road 132/33kV 6039	£357,000	24396	0		wall	1000	14.6	71.6	£180,530	
Humberston	£433,200	22709	0	0	wall	1000	19.1	117.4	£336,093	
Osgodby 132/33kV 7443	£704,000	22328	0		wall	1000	31.5	398.2	£495,682	
Rawmarsh Road	£503,670	18995	1	Pumping Station	wall	1000	26.5	100.7	£421,689	95
Sculcoates B 132kV 8460	£638,000	17771	0		wall	1000	35.9	138.1	£263,011	
Moss Road	£705,420	17322	1	Pumping Station	wall	1000	40.7	161.6	£256,366	
County Road North	£333,115	15290	0	0	wall	200	21.8	230.5	£113,146	
Doughty Road	£136,400	12863	0	0	wall	200	10.6	65.5	£95,186	
Blackburn Meadows B 132/33kV 5578	£484,000	12175	0		wall	1000	39.8	94.1	£90,095	
Sculcoates 'A' 132/11kV 5627	£440,000	12155	0		wall	1000	36.2	148.5	£179,894	
Elgar Road 33/11kV 5622	£170,000	11953	0		wall	100	14.2	106.1	£88,452	
Endike Lane	£962,480	11238	0	0	wall	200	85.6	888.7	£83,161	
Mirfield	£209,000	11020	0	0	wall	100	19.0	196.2	£81,548	
Goole	£438,928	10571	0	0	wall	200	41.5	217.0	£78,225	
Immingham 132/33kV 5	£3,087,000	10503	0		wall	1000	293.9	707.5	£155,444	
Alverthorpe Road 33/11kV 6051	£264,000	9462	0		wall	100	27.9	147.4	£70,019	
Great Coates 33/11kV 12	£242,000	9132	0		wall	1000	26.5	138.4	£135,154	
Buslingthorpe Green 33/11kV 3849	£153,000	9061	0		wall	100	16.9	129.3	£67,051	
North Avenue 33/11kV 5189	£153,000	8684	0		wall	100	17.6	122.8	£64,262	
Millroyd Street	£188,300	8461	0	0	wall	100	22.3	165.6	£62,611	
Conyard Road	£431,090	8199	0	0	wall	1000	52.6	760.3	£121,345	
Thorne 66/11kV (Asc) 45058	£2,088,000	8018	0		wall	200	260.4	1406.1	£59,333	
Tiverton Road	£411,495	7850	0	0	wall	200	52.4	243.8	£58,090	
Todmorden	£2,950,845	7157	0	0	wall	100	412.3	2294.6	£52,962	
Snaith	£0	3082	0	0	Moved and rebuilt out of t	1000	0.0		£0	
Dunston 66/20kV	£440,000	13401	0		wall	1000	32.8	233.7	£197,373	
Dunston 66/11kV	£220,000	7783	0		wall	1000	28.3	107.9	£114,630	
Dunston	£1,500,000	61752	0		wall	1000	24.3	141.1	£909,496	
Billingham Marsh House	£252,000	12805	0		wall	100	19.7	235.1	£94,297	
Foss Islands	£187,000	16506	0		wall	1000	11.3	53.7	£121,552	
Melrosegate	£476,000	49246	0		wall	1000	9.7	48.6	£362,653	

Appendix IV – Temporary Flood Barrier Plans (as at Mar 2012)

The following substations have had plans developed that indicate how temporary flood barriers can be deployed.

Substation
Beal
Bentley
Brighouse
Eastgate Cement
Grainthorpe
Haxey
Hebden Bridge
Ings Lane
Ledston
Leeds Road
Lowfields
Millroyd Street
Rockware
Sandhill Lane
Sherburn
Smith Street
Stainforth
Tadcaster
Tees Industrial

Example Temporary Flood Barrier Plan