R3	457950	525045	1540	8/15
R4	458090	525550	1555	8/16
R5	455680	527395	1351	7/14
R6	455550	527345	1215	6/12
R7	458675	525415	1214	6/12
R8	457895	523735	1139	6/11
R9	458900	525060	983	5/10
R10	458250	523585	977	5/10
R11	459195	524980	867	4/9
$R12_v$	456270	525530	9988	50/100
$R13_a$	456327	525679	6827	34/68
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-24: Maximum 20 minute CO_2 Process Contributions - Scenario 12

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	3500	17/35
$R2_{bn}$	456676	525253	3205	16/32
R3	457950	525045	513	3/5
R4	458090	525550	518	3/5
R5	455680	527395	450	2/5
R6	455550	527345	405	2/4
R7	458675	525415	405	2/4
R8	457895	523735	380	2/4
R9	458900	525060	328	2/3
R10	458250	523585	326	2/3
R11	459195	524980	289	1/3
$R12_v$	456270	525530	3329	17/33

$R13_a$	456327	525679	2276	11/23
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.39 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptor R1 where predicted concentrations are above the Lower Exposure Criteria. This exceedance occurs over a small area, as shown in Figure A19, Appendix A.

3.1.40 A predicted CO_2 concentration of 10,499 ppm (R1v) is above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.41 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2.

Scenario 13

3.1.42 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 13 are shown in Table 3-1 and Table 3-2.

Table 3-25: Maximum 1 hour CO_2 Process Contributions - Scenario 13

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	13414	67/134
$R2_z$	456815	525617	10434	52/104
R3	457950	525045	1797	9/18
R4	458090	525550	1908	10/19
R5	455680	527395	1494	7/15
R6	455550	527345	1386	7/14
R7	458675	525415	1363	7/14
R8	457895	523735	1206	6/12
R9	458900	525060	1112	6/11
R10	458250	523585	1083	5/11
R11	459195	524980	982	5/10
$R12_y$	456241	525455	8618	43/86

R13a	456327	525679	7112	36/71
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-26: Maximum 24 hour CO_2 Process Contributions - Scenario 13

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
R1o	456774	525900	3415	17/34
R2q	456848	525701	1649	8/16
R3	457950	525045	247	1/2
R4	458090	525550	334	2/3
R5	455680	527395	221	1/2
R6	455550	527345	229	1/2
R7	458675	525415	233	1/2
R8	457895	523735	167	1/2
R9	458900	525060	183	1/2
R10	458250	523585	138	1/1
R11	459195	524980	159	1/2
R12z	456237	525446	1137	6/11
R13a	456327	525679	1092	5/11
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.43 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptors R1 and R2 where predicted concentrations are above the Lower Exposure Criteria. This exceedance occurs over a small area, as shown in Figure A20, Appendix A.

3.1.44 The predicted CO_2 concentrations of 13,414 ppm (R1v) and 10,434 ppm (R2z)are above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.45 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2. The isopleth plot for 24 hour CO_2 is shown in Figure A21, Appendix A.

Scenario 14

3.1.46 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 14 are shown in Table 3-1 and Table 3-2.

Table 3-27: Maximum 1 hour CO_2 Process Contributions - Scenario 14

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	12823	64/128
$R2_z$	456815	525617	10434	52/104
R3	457950	525045	1522	8/15
R4	458090	525550	1683	8/17
R5	455680	527395	1368	7/14
R6	455550	527345	1268	6/13
R7	458675	525415	1230	6/12
R8	457895	523735	1071	5/11
R9	458900	525060	990	5/10
R10	458250	523585	966	5/10
R11	459195	524980	878	4/9
$R12_a$	456327	525679	7112	36/71
$R13_a$	456327	525679	7112	36/71
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-28: Maximum 20 minute CO_2 Process Contributions - Scenario 14

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		

$R1_v$	456709	525925	4274	21/43
$R2_z$	456815	525617	3478	17/35
R3	457950	525045	507	3/5
R4	458090	525550	561	3/6
R5	455680	527395	456	2/5
R6	455550	527345	423	2/4
R7	458675	525415	410	2/4
R8	457895	523735	357	2/4
R9	458900	525060	330	2/3
R10	458250	523585	322	2/3
R11	459195	524980	293	1/3
$R12_a$	456327	525679	2371	12/24
$R13_a$	456327	525679	2371	12/24
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.47 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptors R1 and R2 where predicted concentrations are above the Lower Exposure Criteria over a small area, as shown in Figure A22, Appendix A.

3.1.48 The predicted CO_2 concentrations of 12,843 ppm (R1v) and 10,434 ppm (R2z)are above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.49 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2.

4 CONCLUSIONS

4.1.1 H2 Teesside Limited has undertaken an assessment of CO_2 venting scenarios in support of their Environmental Perit application process.

4.1.2 AECOM has carried out dispersion modelling of fourteen identified scenarios which are considered to potentially result in the worst-case impacts at human health receptors from the Proposed Installation.

4.1.3 Of the fourteen scenarios assessed, Scenario 1 results in the highest concentrations of CO_2 beyond the Proposed Installation site boundary, which a maximum concentration of 14,389 ppm being predicted to occur on the Northern Proposed Installation site boundary. This occurs outside of the Proposed Installation, but still within the wider industrial area, where there is no access for members of the public. Predicted concentrations in locations where public exposure could occur, if people were present at the time of the impact, were lower than 10,000 ppm. In addition, although 14,389 ppm is above the Lower Exposure Criteria applied to the assessment, it is below the limit for the onset of symptoms (20,000 ppm).

4.1.4 It is therefore considered that the use of 10,000 ppm as the Exposure Criteria for the assessment is conservative, and that all predicted PCs are below the Upper Exposure Criteria indicating it is unlikely that symptoms due to CO_2 toxicity would be reported at offsite locations.

5 APPENDIX A FIGURES

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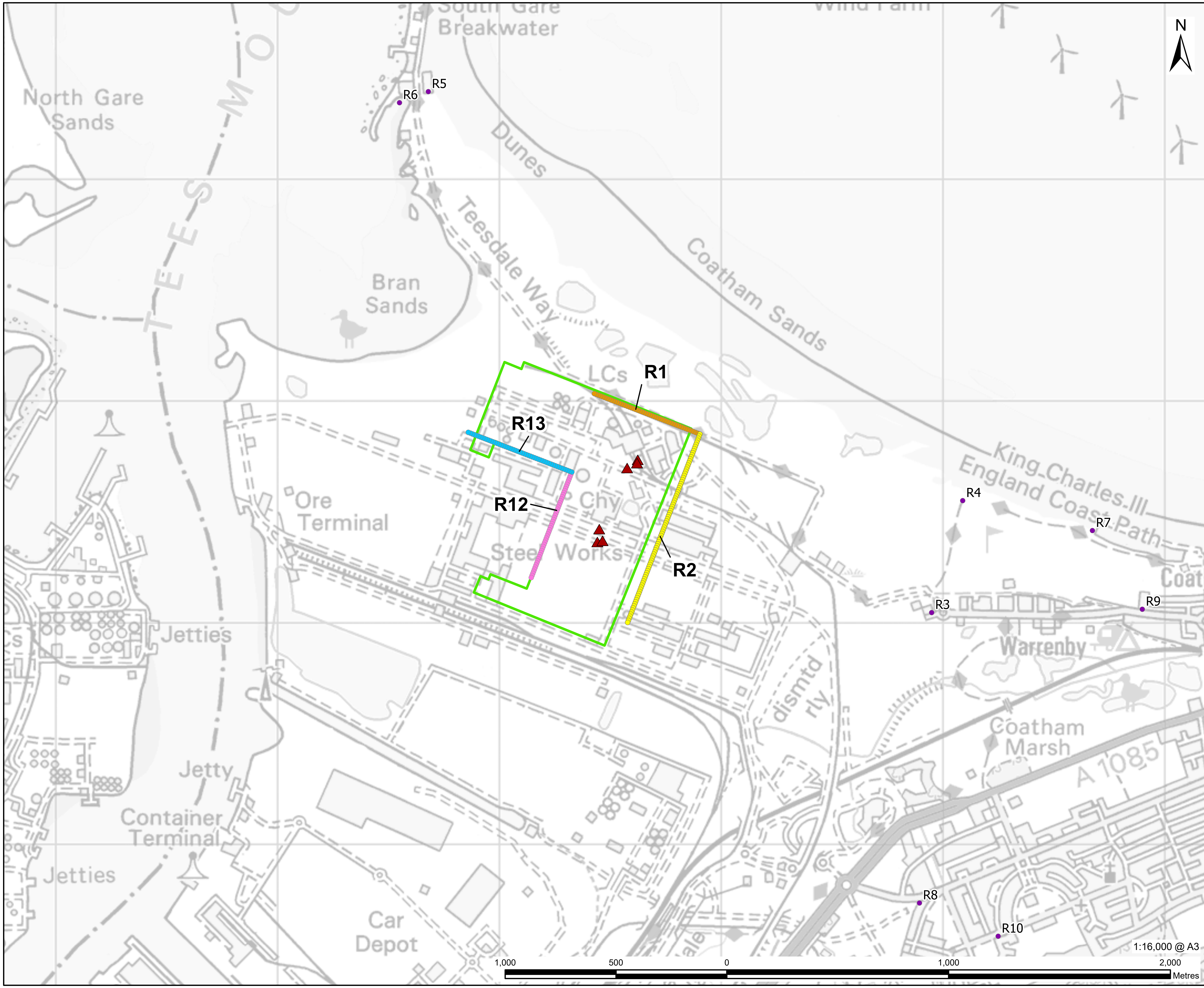

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H2 Teesside Limited

CONSULTANT

AECOM Limited
100 Embankment,
Cathedral Approach,
Manchester, M3 7FB
www.aecom.com

LEGEND

Permitting Site Boundary

Sources

Receptors

R1

R2

R3 to R11

R12

R13

NOTES

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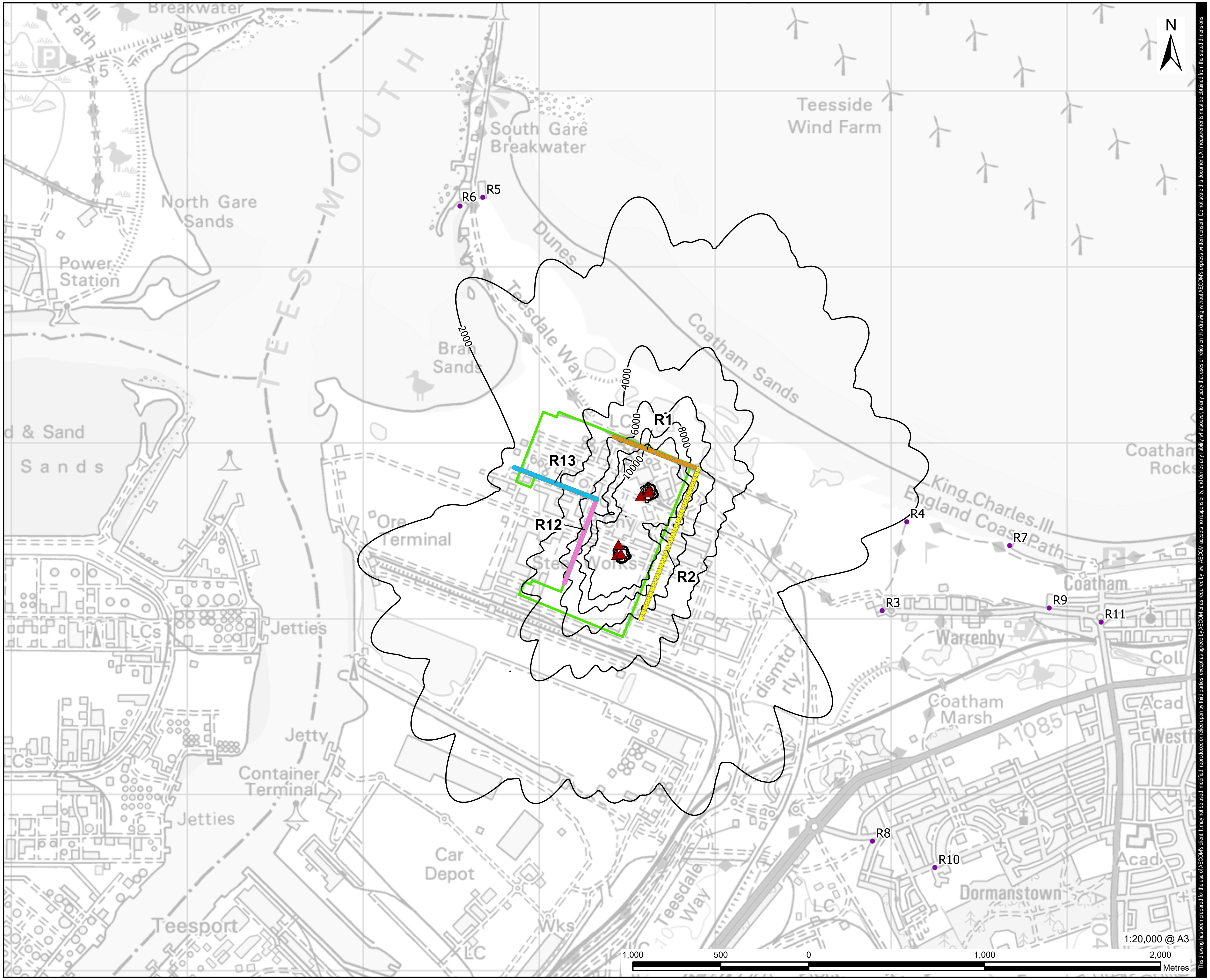
FIGURE TITLE

Air Quality Study Area CO_2 Assessment

FIGURE NUMBER

Figure A1



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Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

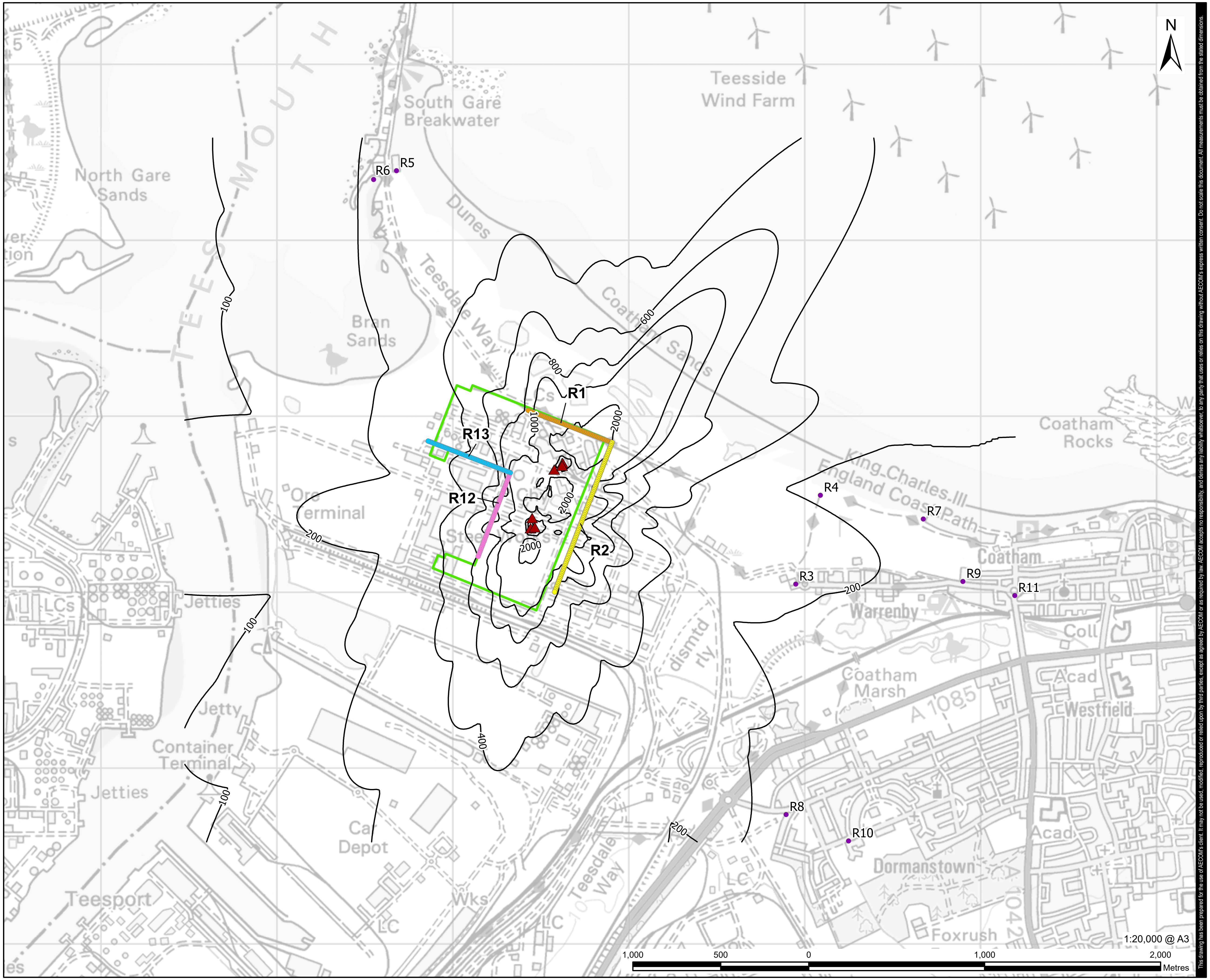
60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 1 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A2



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LEGEND

- Permitting Site Boundary
- Sources
- Receptors
  - R1
  - R2
  - R3 to R11
  - R12
  - R13
- 24 hour CO_2 Process Contribution (ppm)

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FIGURE TITLE

24h CO_2 Process Contribution for the Proposed Development during Scenario 1 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER

Figure A3

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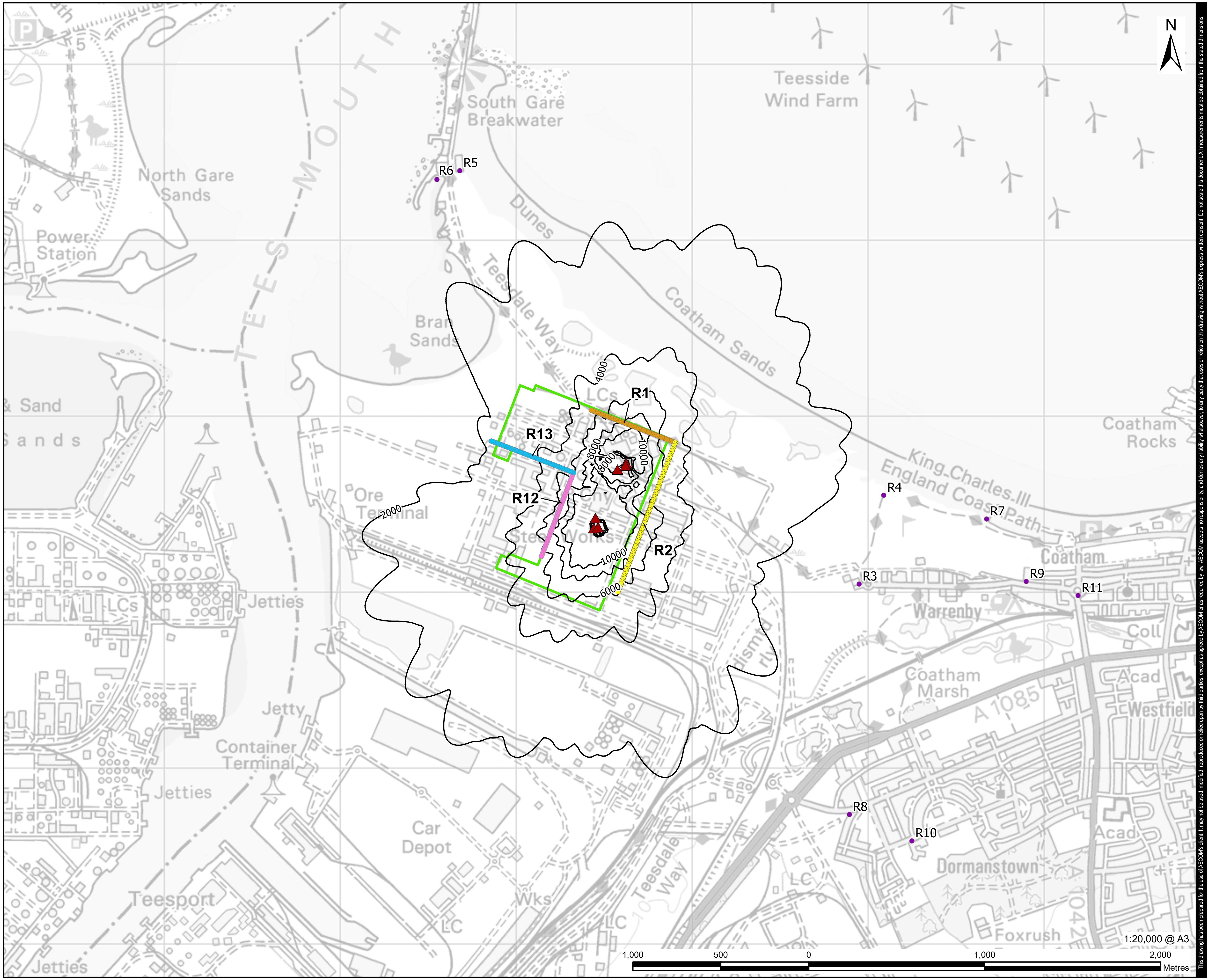

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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

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PROJECT NUMBER

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FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 2 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A4

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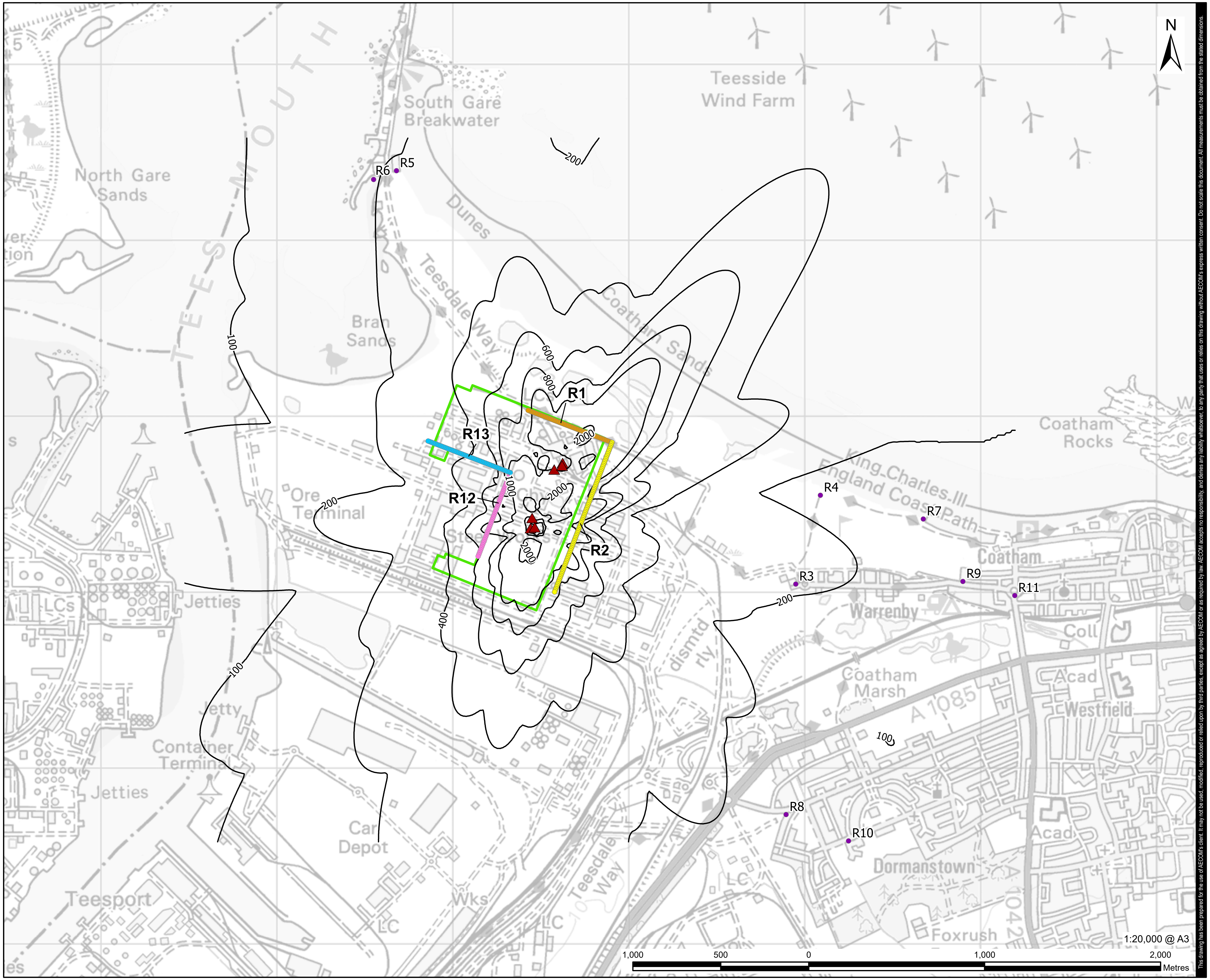

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LEGEND

- Permitting Site Boundary
- Sources
- Receptors
  - R1
  - R2
  - R3 to R11
  - R12
  - R13
- 24 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

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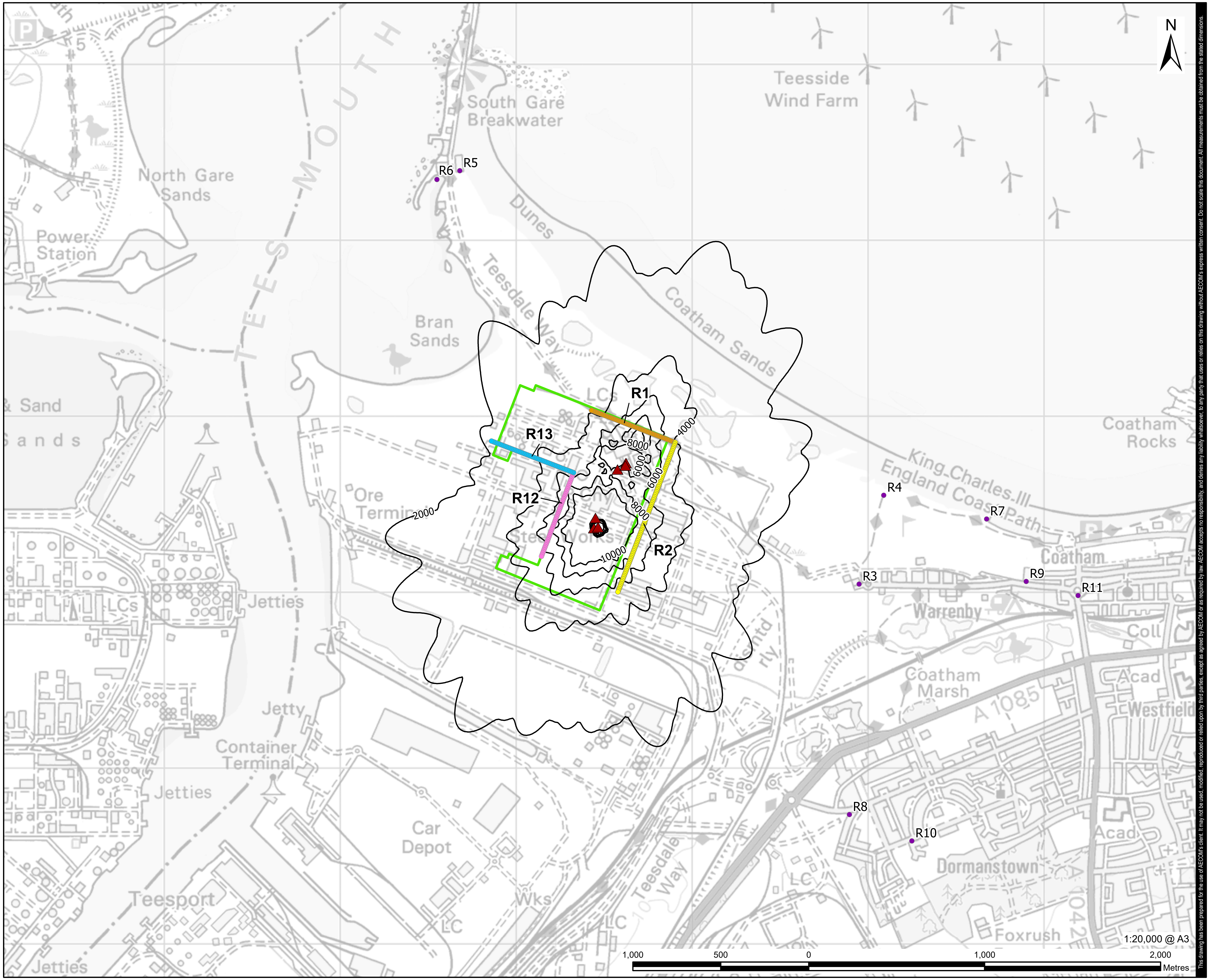
FIGURE TITLE

24h CO_2 Process Contribution for the Proposed Development during Scenario 2 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER

Figure A5



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Cathedral Approach,
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

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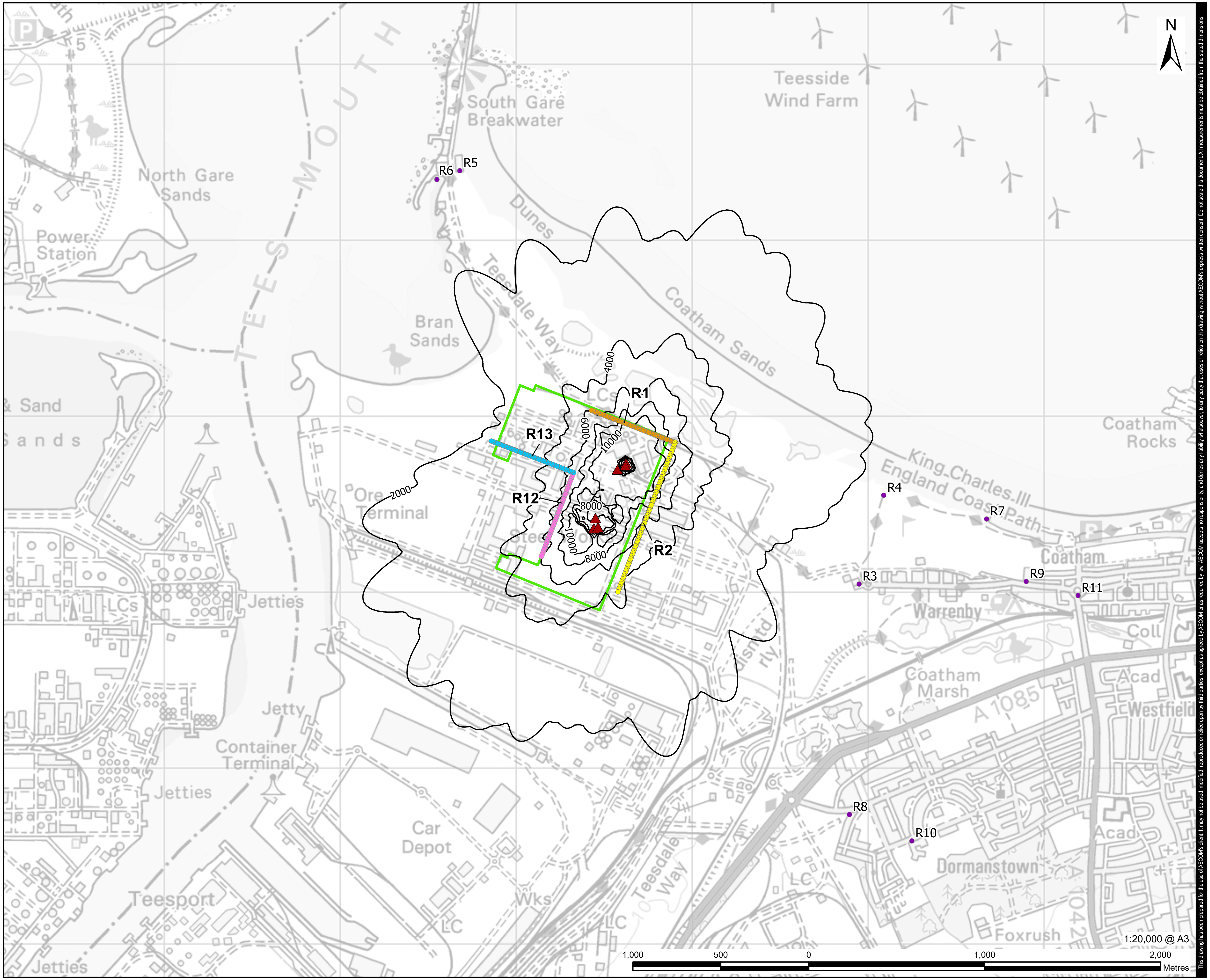
FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 3 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A6



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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE
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PROJECT NUMBER
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FIGURE TITLE
1h CO_2 Process Contribution for the Proposed Development during Scenario 4 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER
Figure A7

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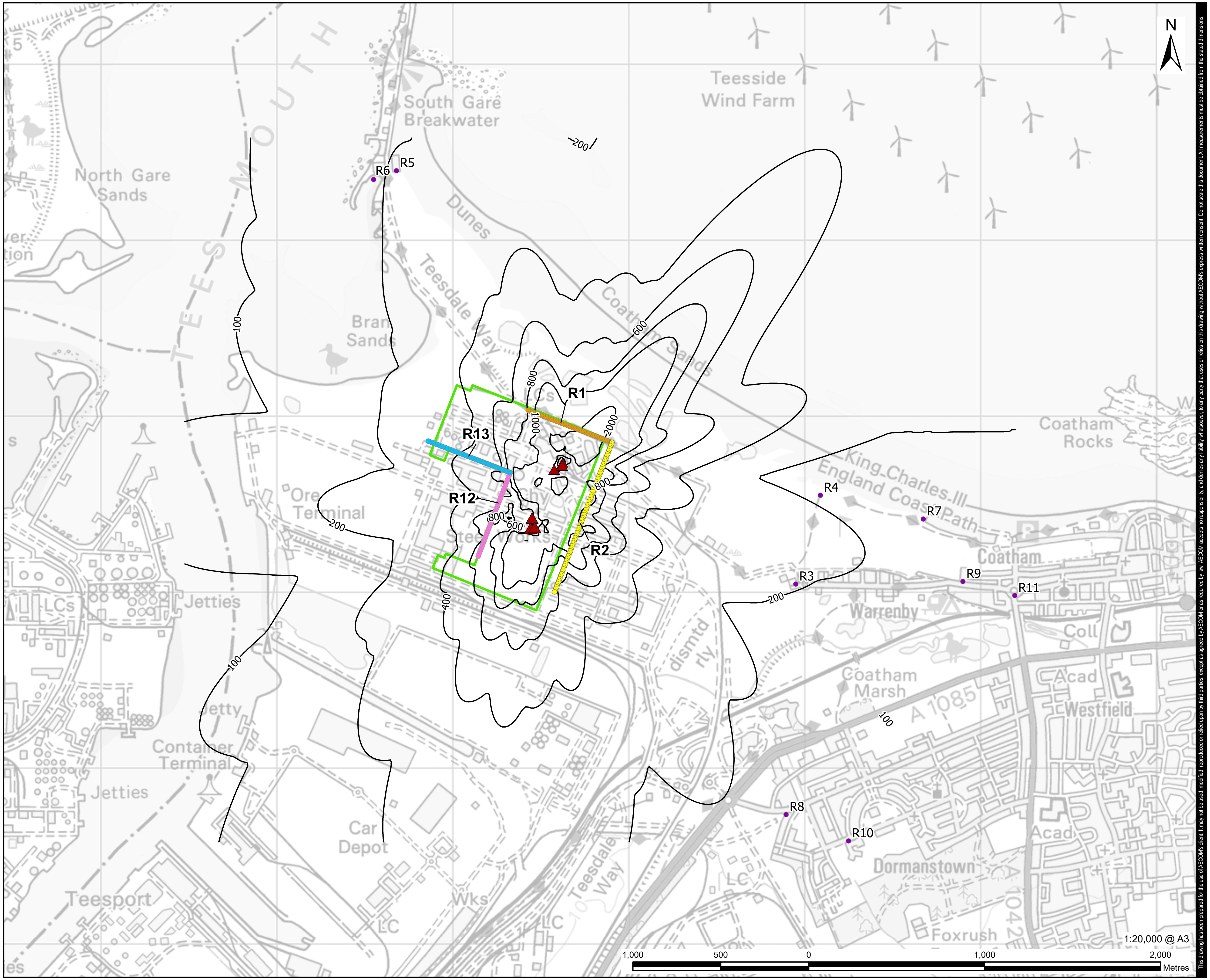

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LEGEND

- Permitting Site Boundary
- Sources
- Receptors
  - R1
  - R2
  - R3 to R11
  - R12
  - R13
- 24 hour CO_2 Process Contribution (ppm)

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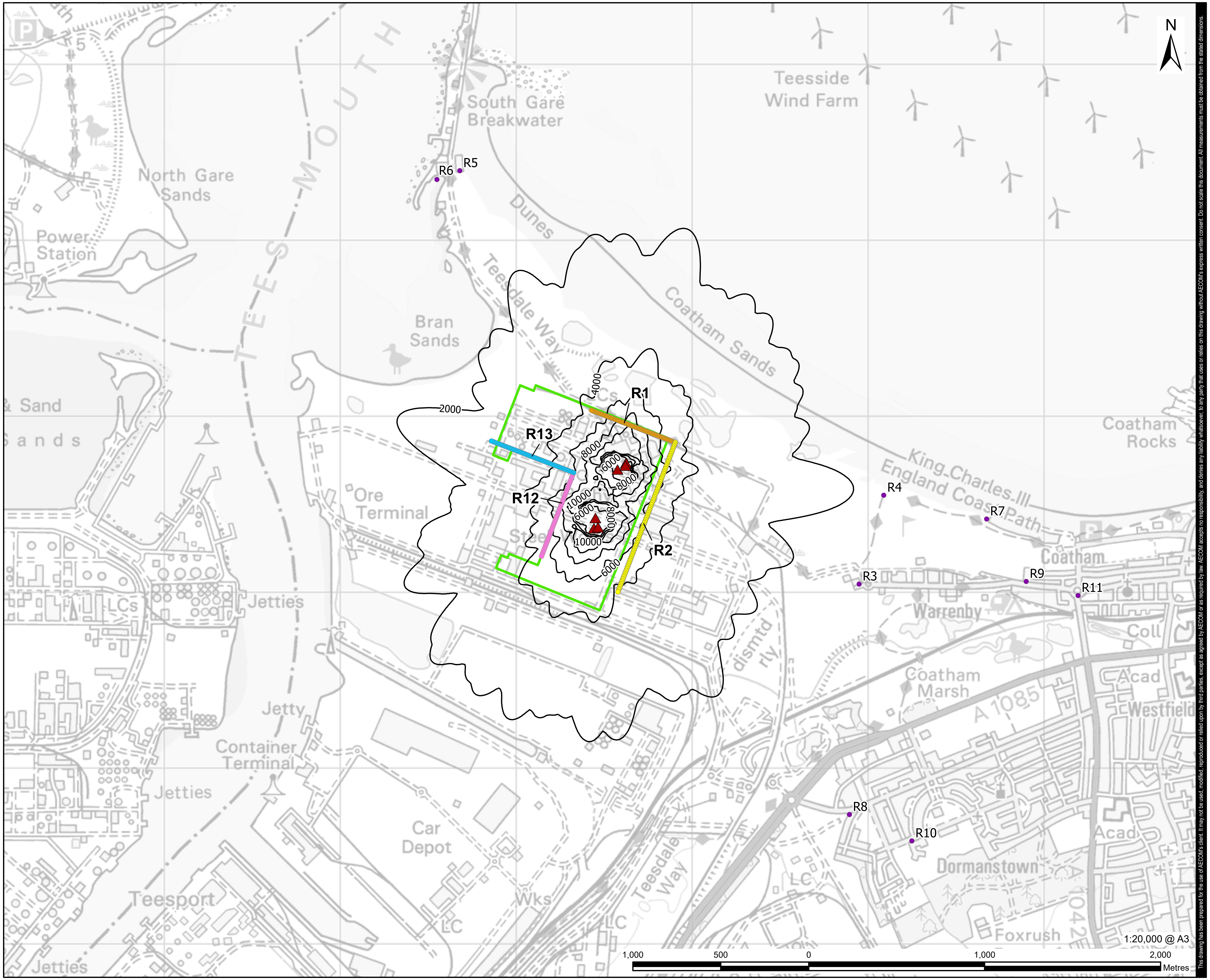
FIGURE TITLE

24h CO_2 Process Contribution for the Proposed Development during Scenario 4 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER

Figure A8



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Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

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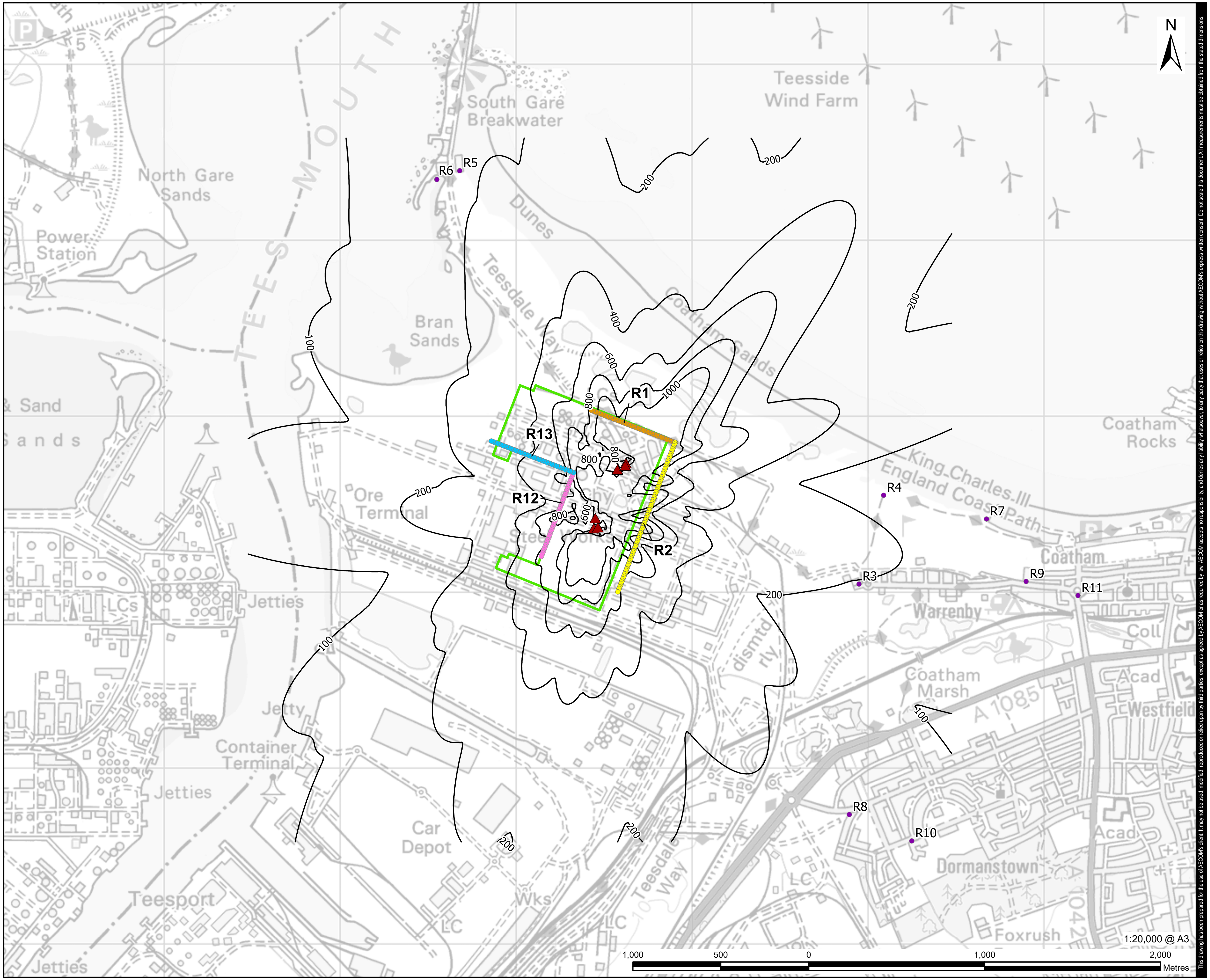
FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 5 – for the Worst Affected Meteorological Year of 2022

FIGURE NUMBER

Figure A9



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CONSULTANT

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100 Embankment,
Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 24 hour CO_2 Process Contribution (ppm)

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FIGURE TITLE

24h CO_2 Process Contribution for the Proposed Development during Scenario 5 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER

Figure A10

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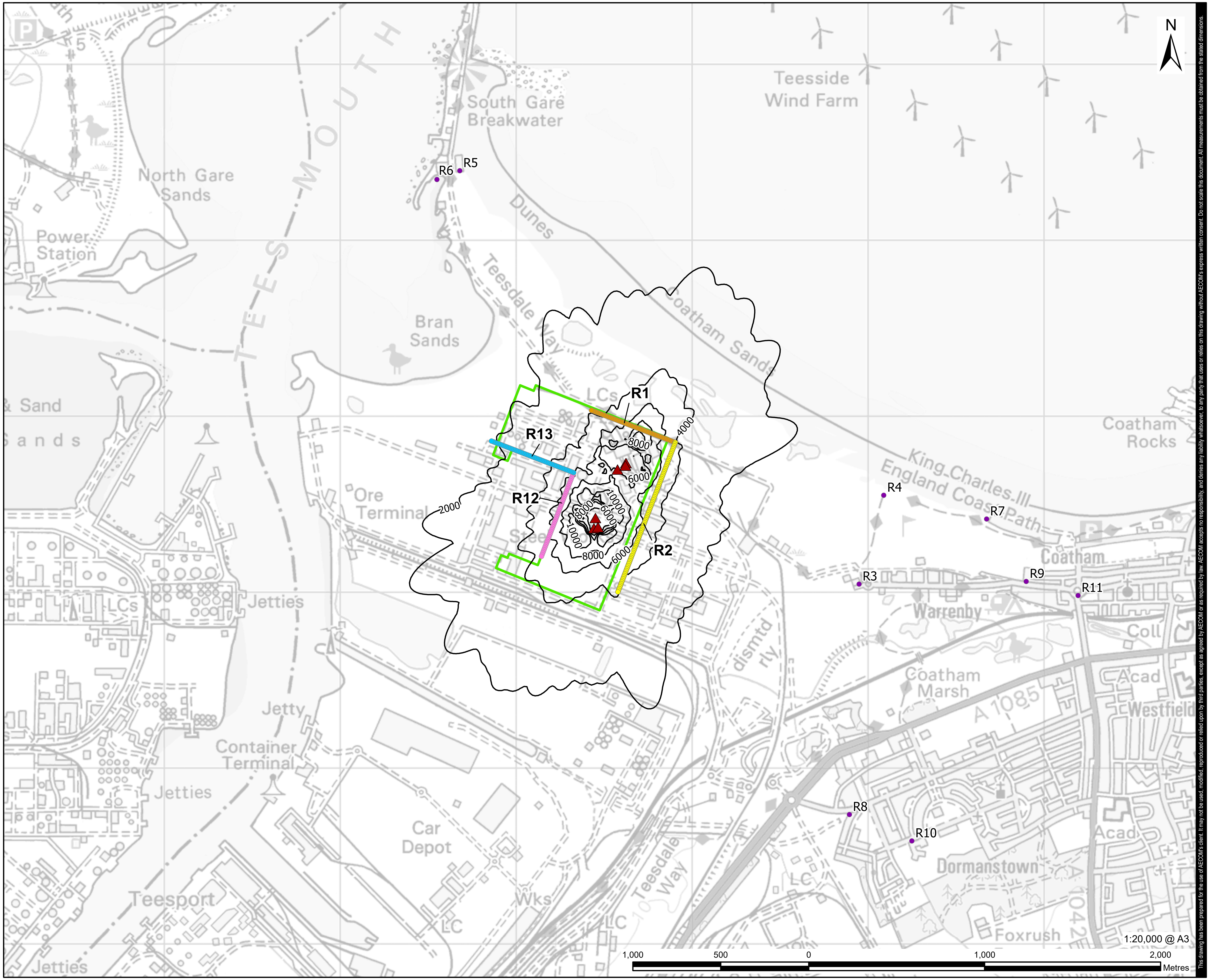

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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

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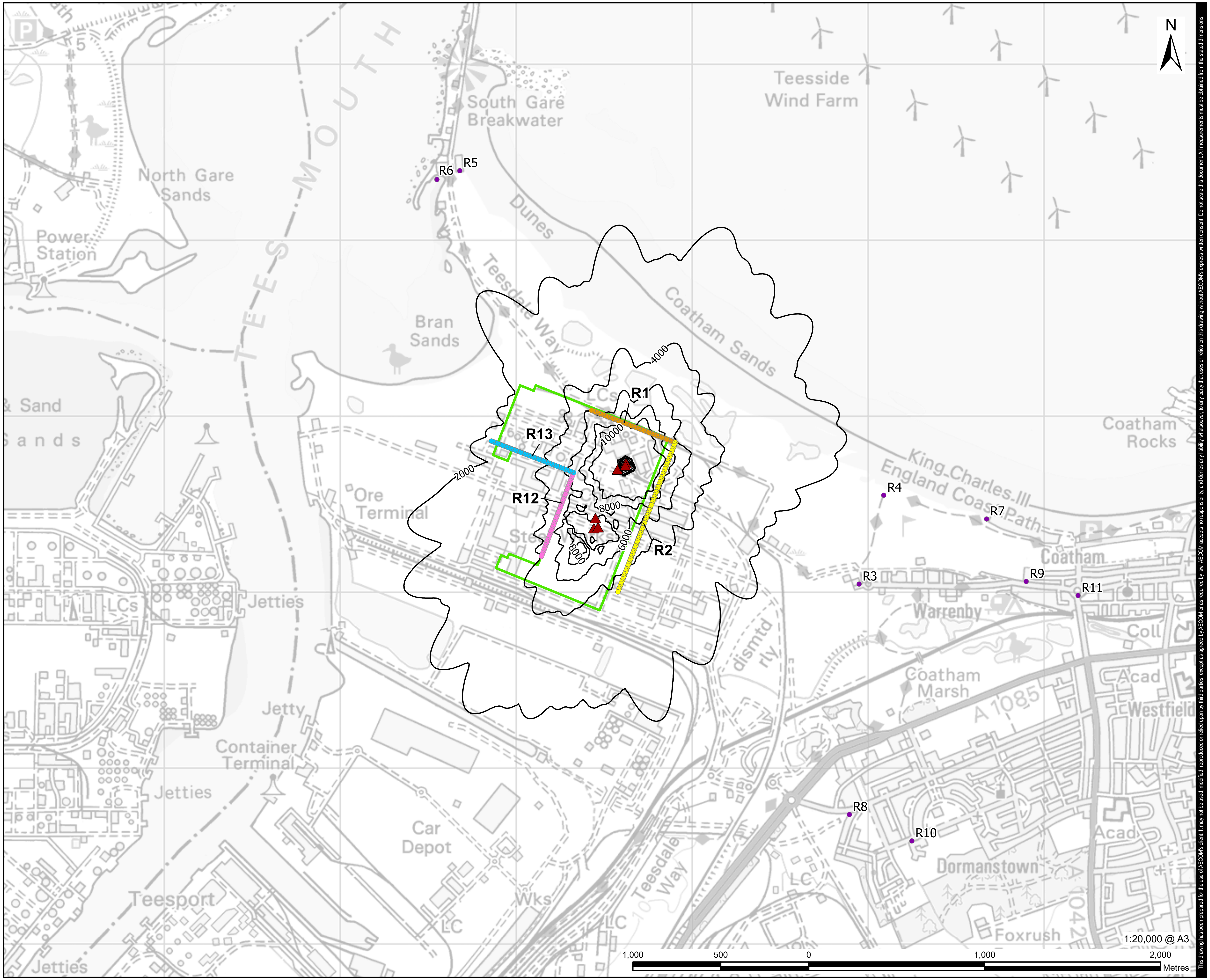
FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 6 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A11



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CONSULTANT

AECOM Limited
100 Embankment,
Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

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ISSUE PURPOSE

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PROJECT NUMBER

60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 7 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A12

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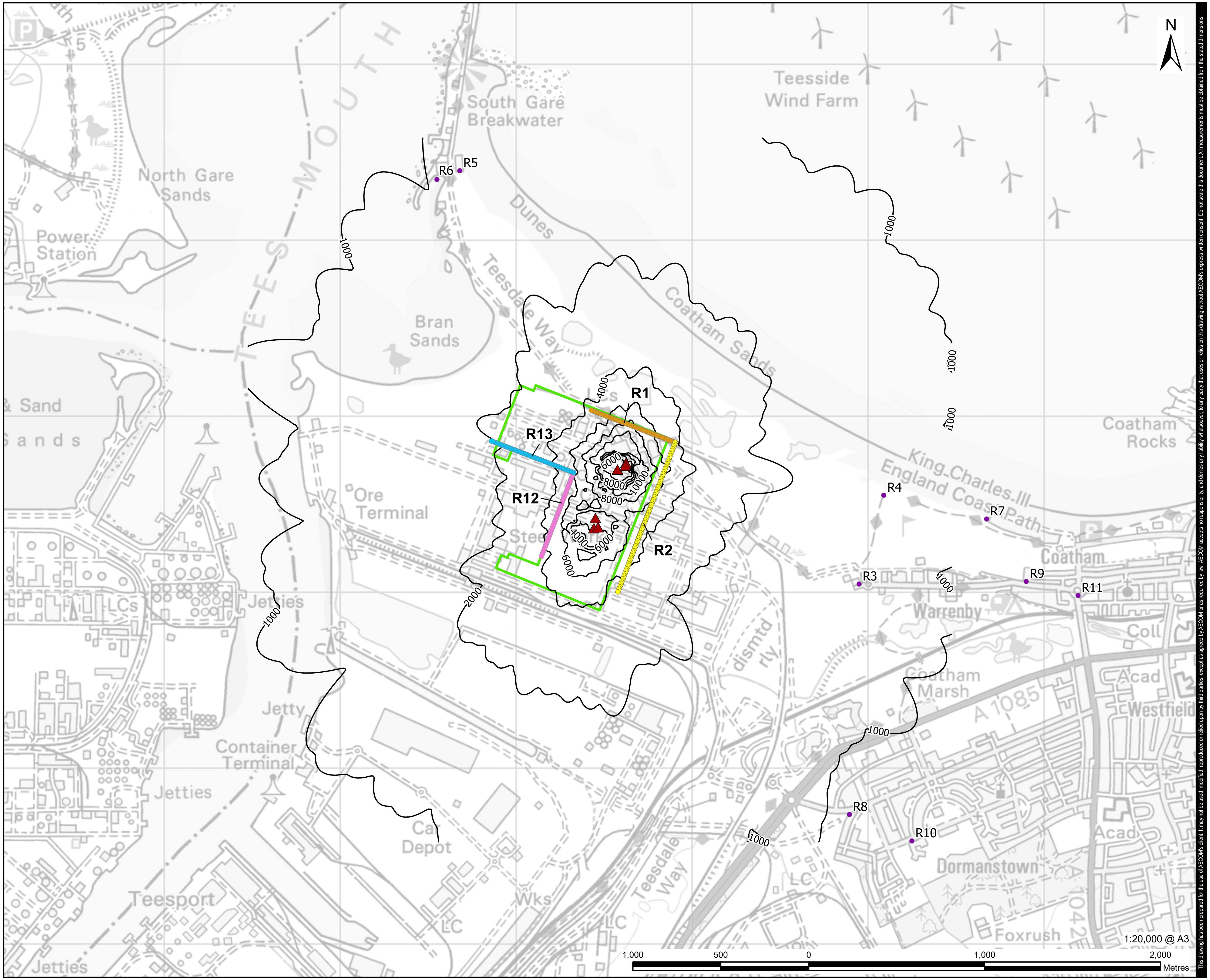

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Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

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ISSUE PURPOSE

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PROJECT NUMBER

60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 8 – for the Worst Affected Meteorological Year of 2022

FIGURE NUMBER

Figure A13

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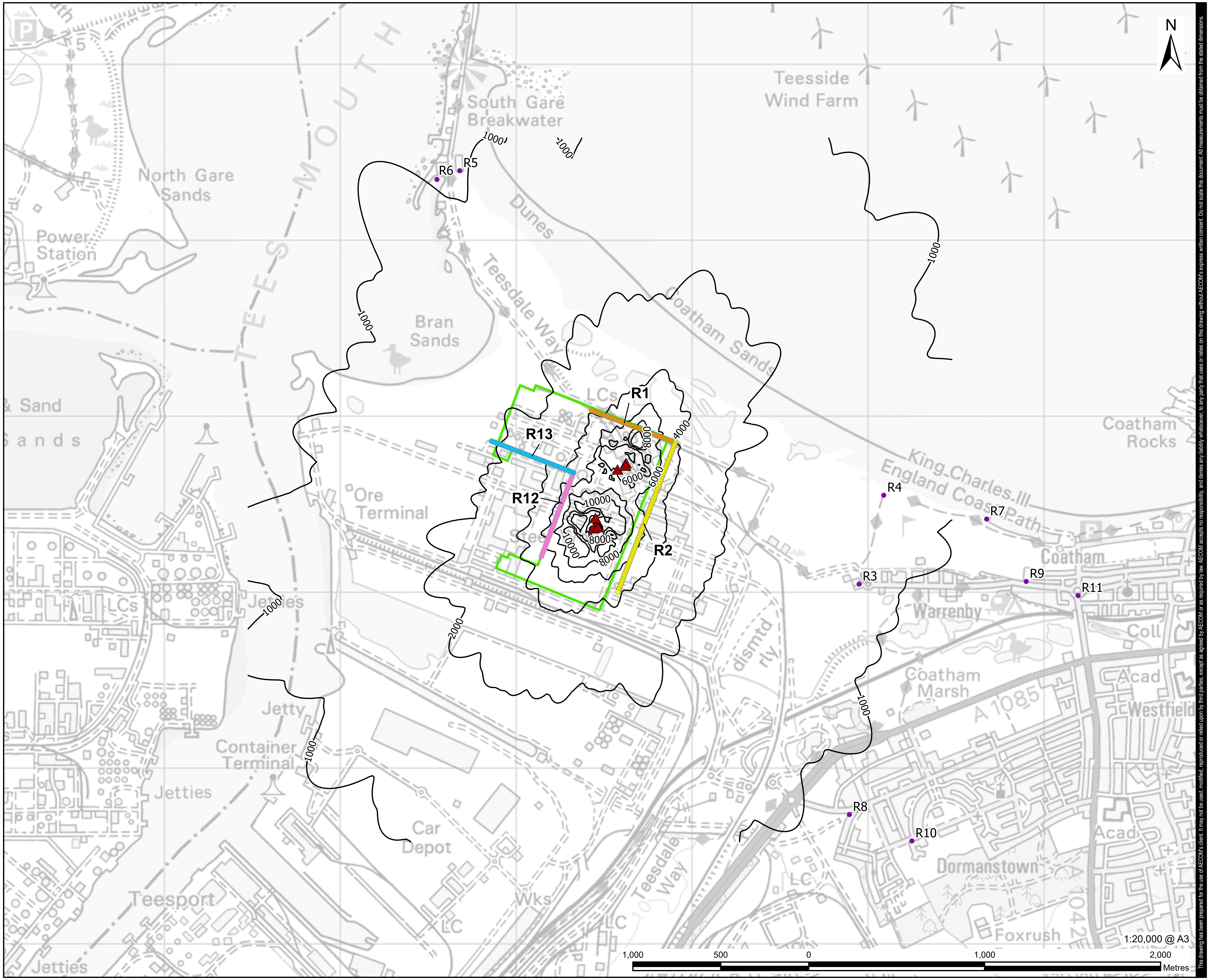

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Cathedral Approach,
Manchester, M3 7FB
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LEGEND

Permitting Site Boundary

Sources

Receptors

R1

R2

R3 to R11

R12

R13

1 hour CO_2 Process Contribution (ppm)

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ISSUE PURPOSE

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PROJECT NUMBER

60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 9 – for the Worst Affected Meteorological Year of 2019.

FIGURE NUMBER

Figure A14

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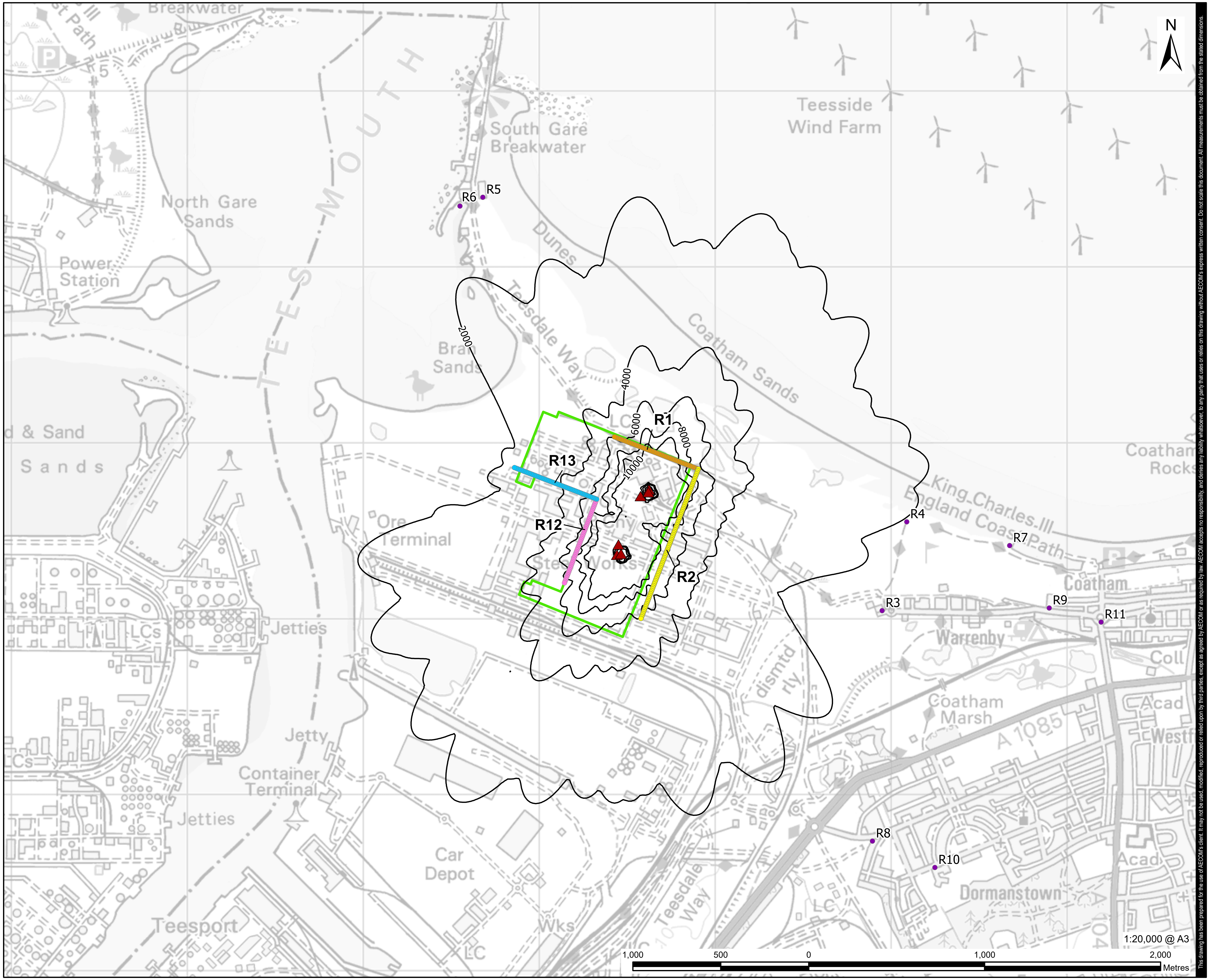

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Cathedral Approach,
Manchester, M3 7FB
www.aecom.com

LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

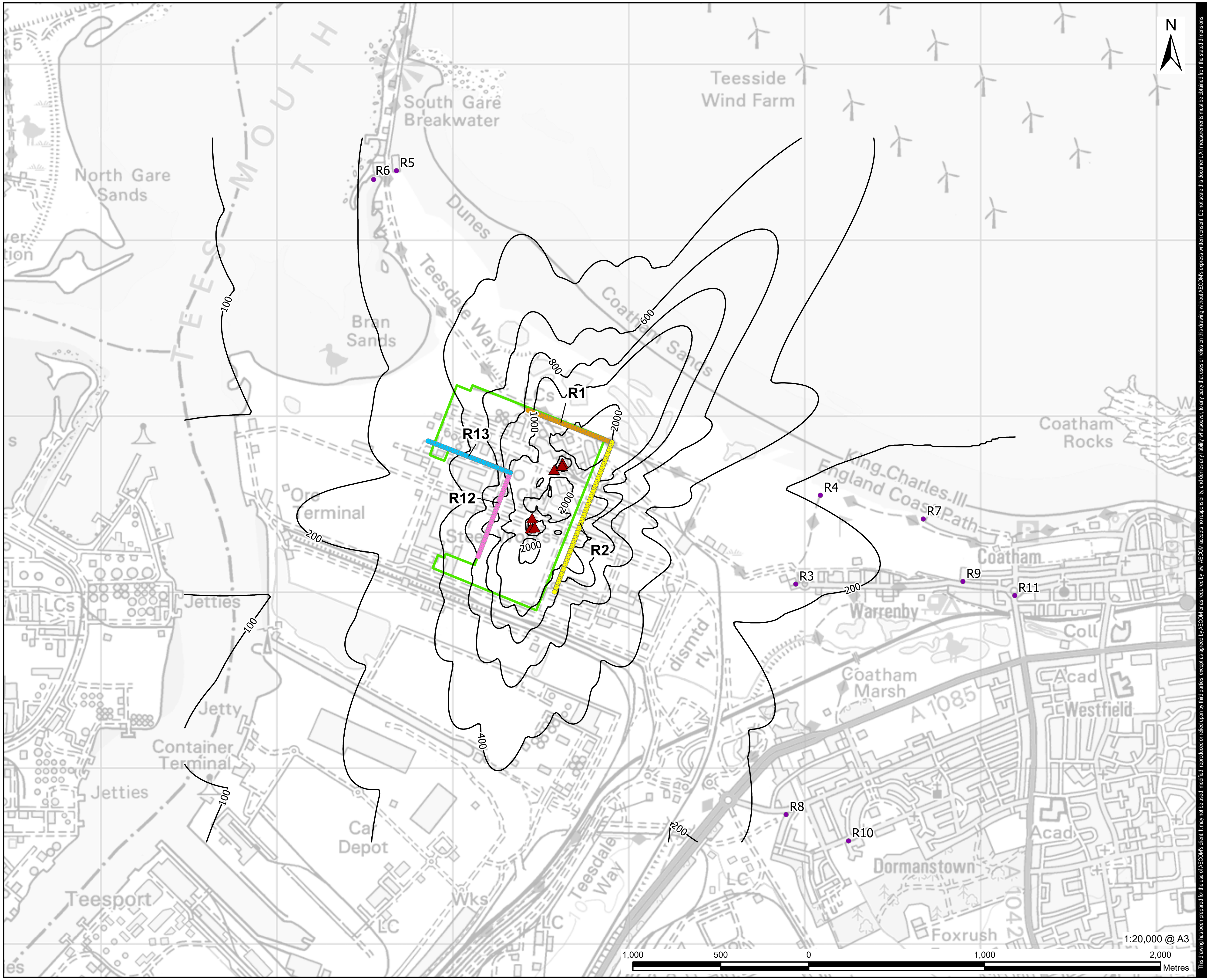
60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 10 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A15



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AECOM Limited
100 Embankment,
Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources
- Receptors
  - R1
  - R2
  - R3 to R11
  - R12
  - R13
- 24 hour CO_2 Process Contribution (ppm)

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PROJECT NUMBER

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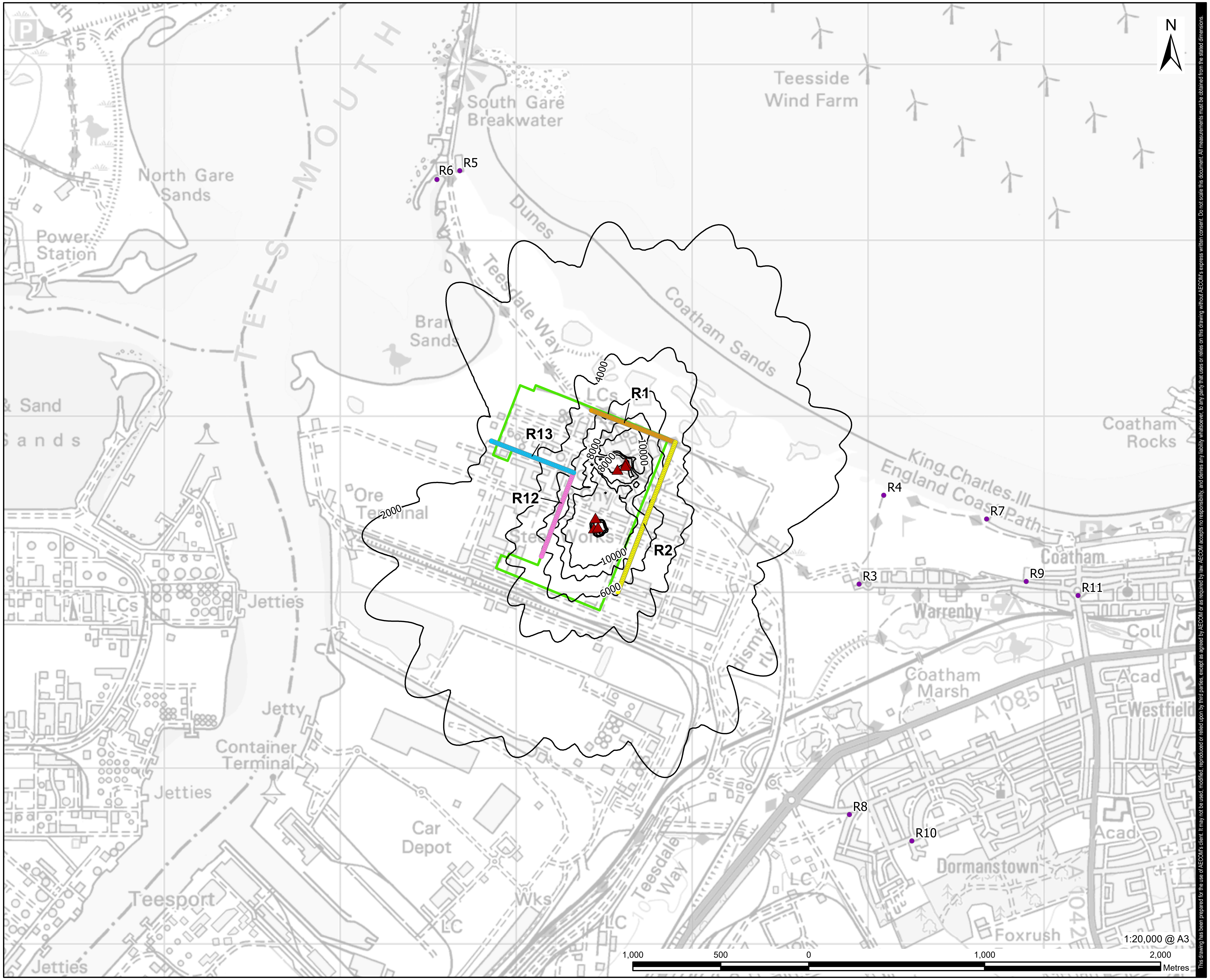
FIGURE TITLE

24h CO_2 Process Contribution for the Proposed Development during Scenario 10 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER

Figure A16



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APPLICANT

H2 Teesside Limited

CONSULTANT

AECOM Limited
100 Embankment,
Cathedral Approach,
Manchester, M3 7FB
www.aecom.com

LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 11 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A17

Revision: 0 Drawn: MM Checked: CL Approved: AD Date: 2024-10-11
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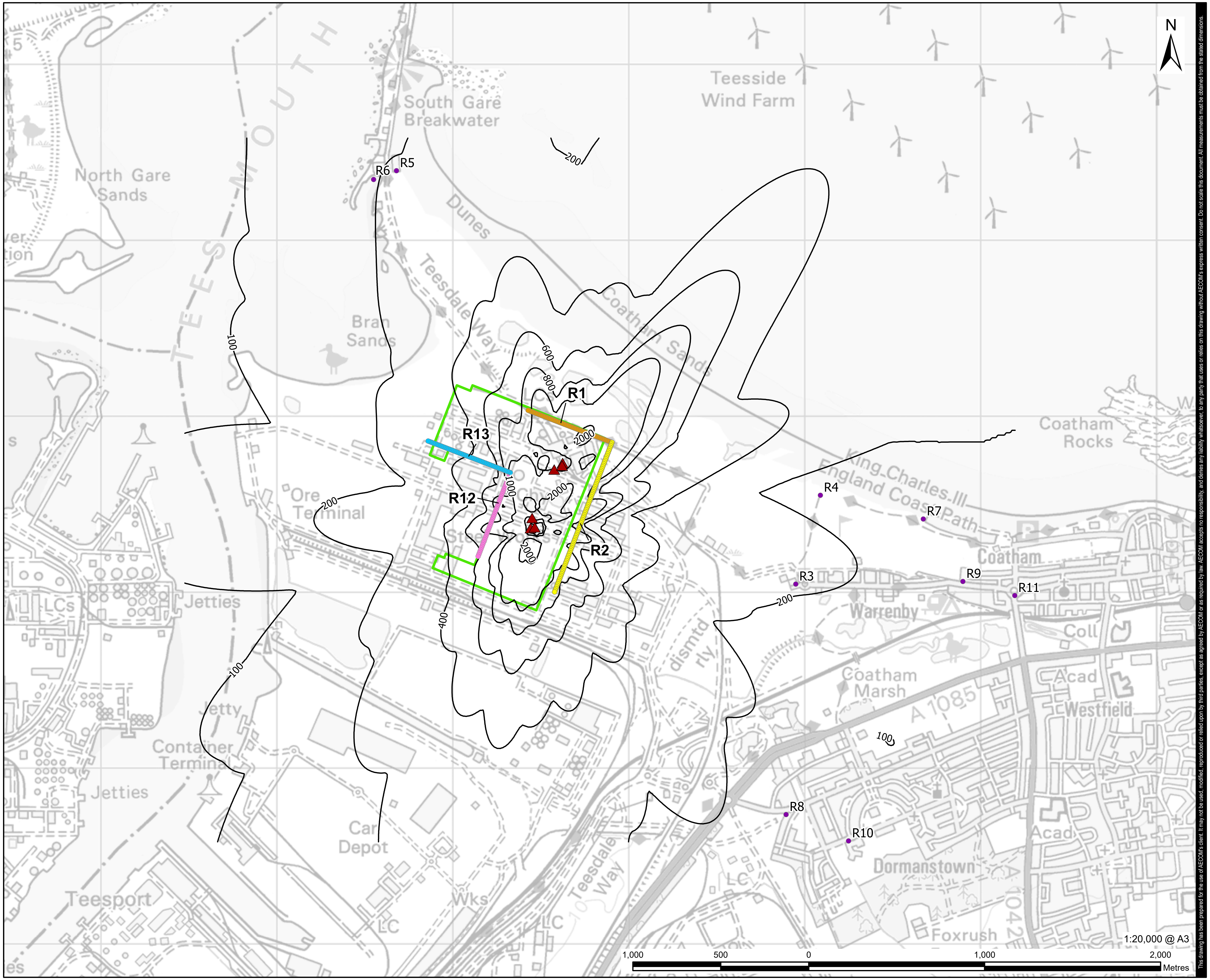

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LEGEND
- Permitting Site Boundary
- Sources

Receptors
- R1
- R2
- R3 to R11
- R12
- R13
- 24 hour CO_2 Process Contribution (ppm)

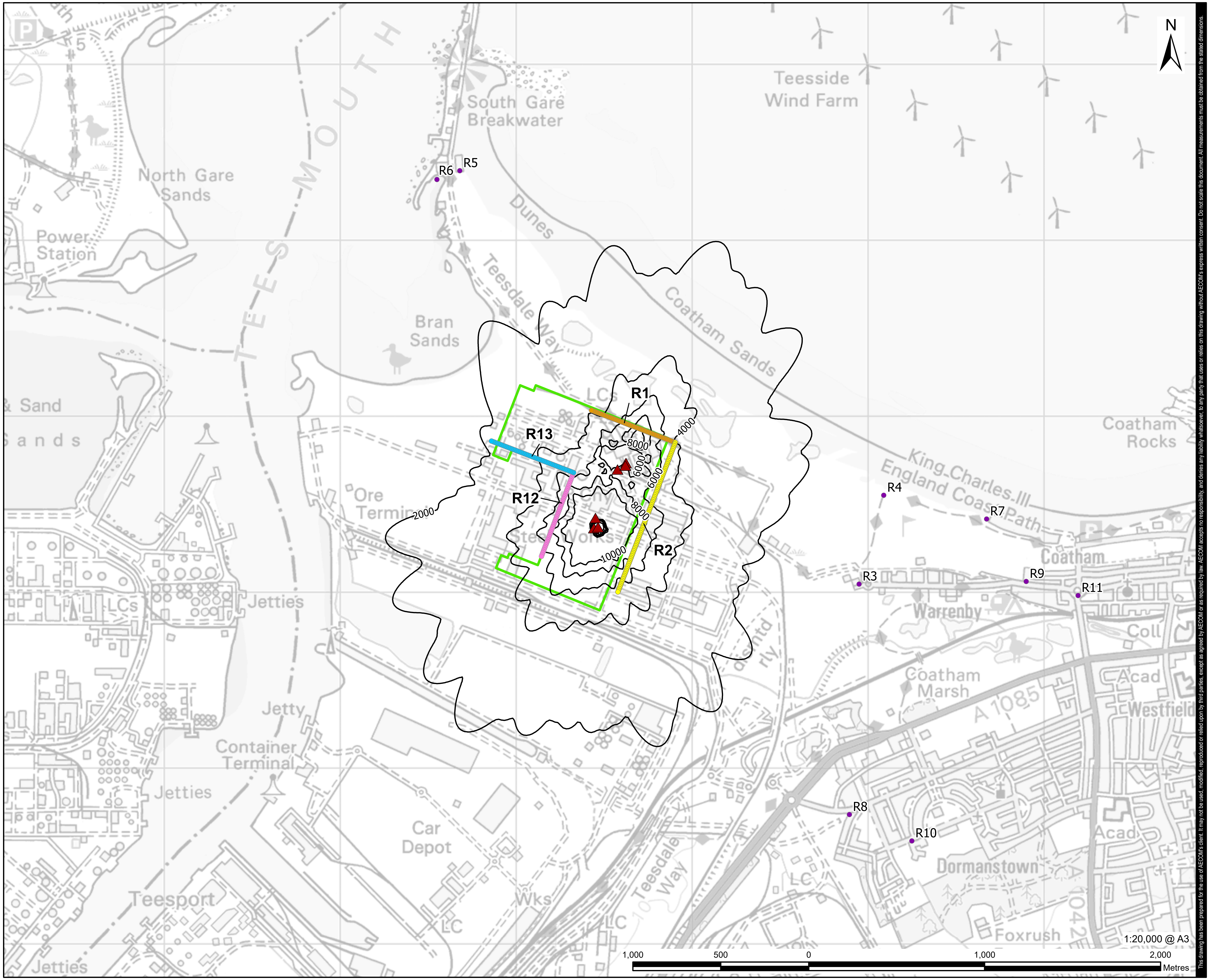
NOTES

ISSUE PURPOSE
Permitting

PROJECT NUMBER
60689030

FIGURE TITLE
24h CO_2 Process Contribution for the Proposed Development during Scenario 11 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER
Figure A18



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Cathedral Approach,
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

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PROJECT NUMBER

60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 12 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A19

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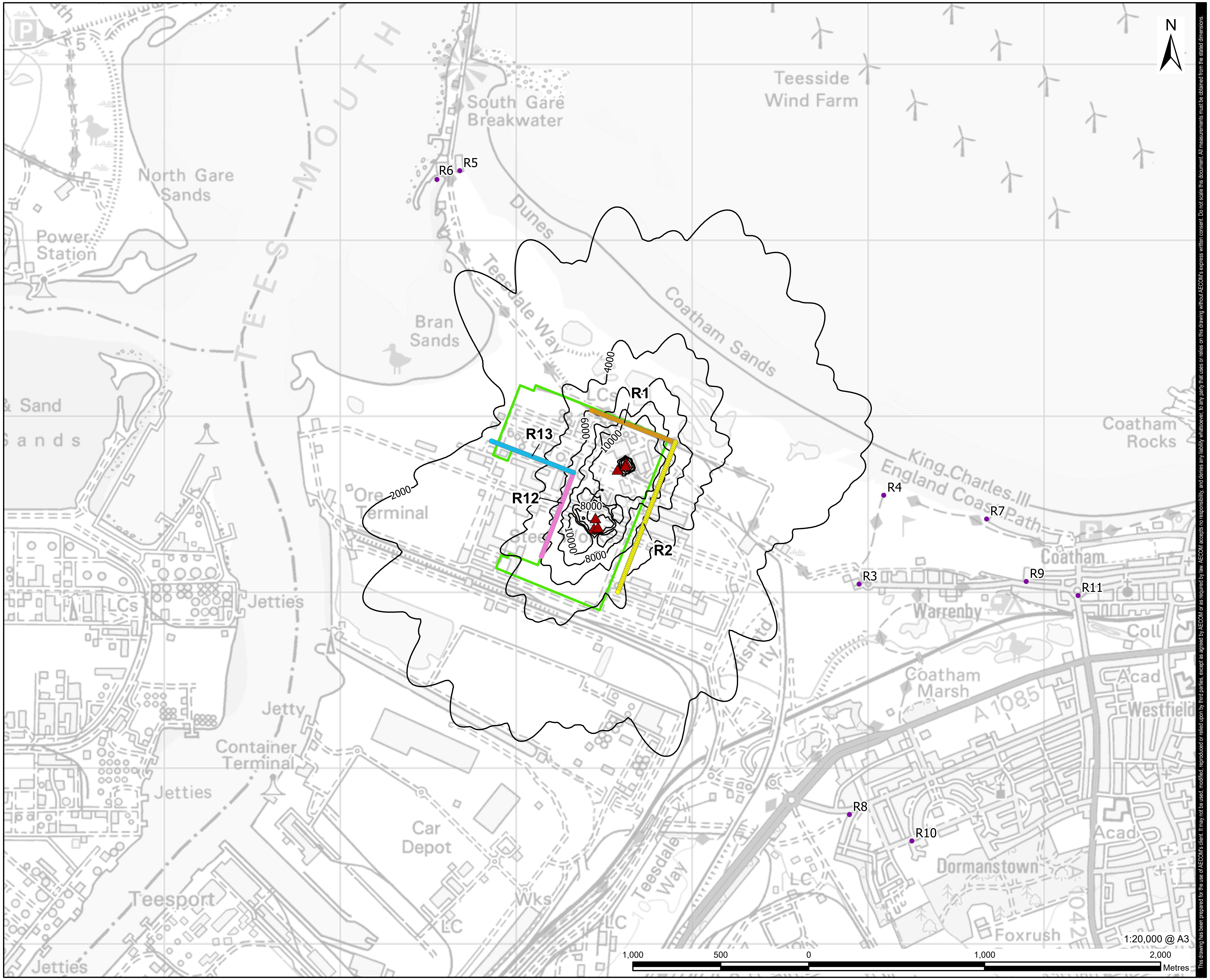

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CONSULTANT

AECOM Limited
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Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources
- Receptors
  - R1
  - R2
  - R3 to R11
  - R12
  - R13
- 1 hour CO_2 Process Contribution (ppm)

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ISSUE PURPOSE

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PROJECT NUMBER

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FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 13 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A20

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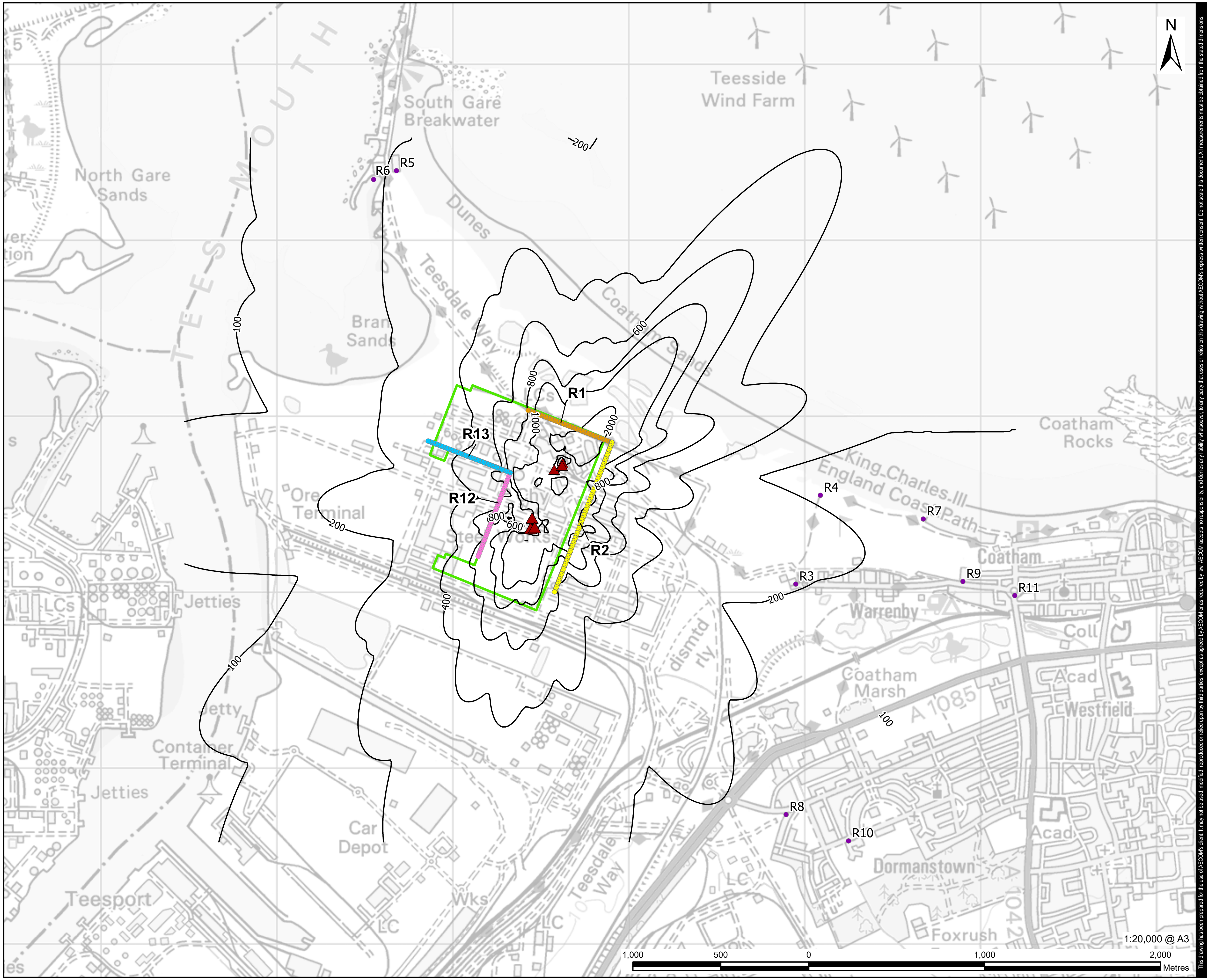

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H2 Teesside Limited

CONSULTANT

AECOM Limited
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Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources
- Receptors
  - R1
  - R2
  - R3 to R11
  - R12
  - R13
- 24 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

60689030

FIGURE TITLE

24h CO_2 Process Contribution for the Proposed Development during Scenario 13 – for the Worst Affected Meteorological Year of 2021

FIGURE NUMBER

Figure A21

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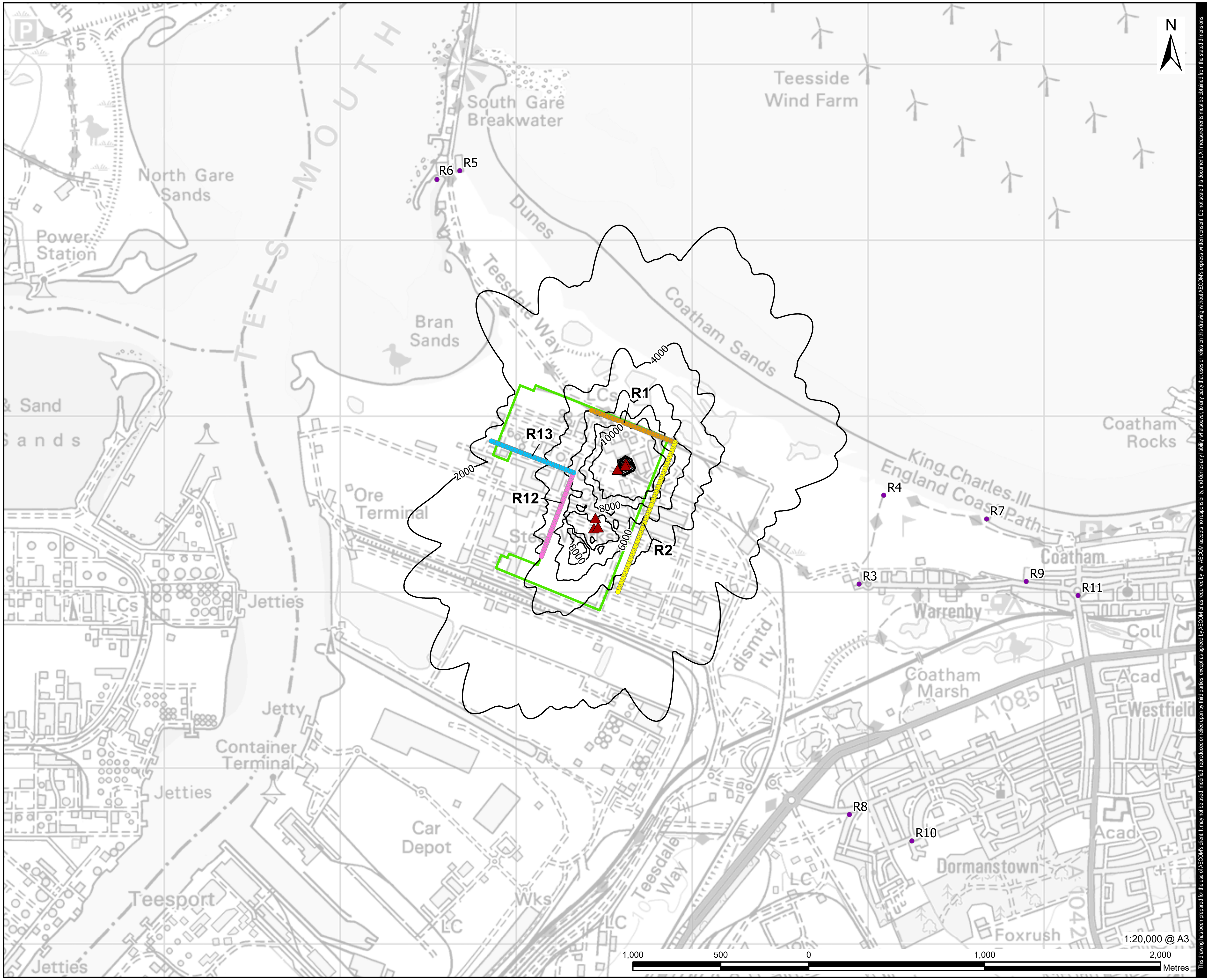

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H2 Teesside Limited

CONSULTANT

AECOM Limited
100 Embankment,
Cathedral Approach,
Manchester, M3 7FB
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LEGEND

- Permitting Site Boundary
- Sources

Receptors

- R1
- R2
- R3 to R11
- R12
- R13
- 1 hour CO_2 Process Contribution (ppm)

NOTES

ISSUE PURPOSE

Permitting

PROJECT NUMBER

60689030

FIGURE TITLE

1h CO_2 Process Contribution for the Proposed Development during Scenario 14 – for the Worst Affected Meteorological Year of 2019

FIGURE NUMBER

Figure A22

6 APPENDIX B SENSITIVITY ANALYSIS

6.1.1 A sensitivity analysis was conducted to determine the most appropriate dispersion model to use for CO_2 releases. Dispersion models calculate the dispersion of a pollutant from a source using an assumption that the release is at least the same density as air, or is at ambient temperature or above, allowing it to disperse into the atmosphere using gaussian distribution calculations to calculate the expected concentration at a particular distance from the plume centre line.

6.1.2 CO_2 is a common component of combustion gases, constituting approximately 5% of the emission. When released as such, it readily mixes with other combustion gases and disperses into the atmosphere as other gases do, without any stratification or separation. However, when released at high concentrations, CO_2 is a dense gas and does not readily mix into the atmosphere without turbulence. This can result in such a CO_2 emission sinking to the lowest ground level, potentially flowing downhill or pooling in areas such as ditches, ponds or sumps.

6.1.3 During the carbon capture process, CO_2 is captured and processed to create a pure, or highly pure, gas, stored under pressure or at temperatures as low as -80°C to allow it to be transported as a fluid. A release of CO_2 at such conditions therefore could result in a plume that sinks to ground level and be transported significant distances without dispersing. Standard dispersion models therefore may not be suitable for modelling such CO_2 releases, as they are unable to consider releases that behave in this manner.

6.1.4 Two commercially available models have been identified that could model dense gases: GASTAR and ADMS6. Both models are readily available in the UK, and both have been used for Environmental Permit and Planning applications. GASTAR is a dense gas dispersion model for emergency and accident release modelling, while ADMS 6 is a general purpose dispersion model that is capable of modelling dense gases.

6.1.5 Model performance has been compared between both models to take into account a number of sensitivity tests for each of the modelled scenarios. These are:

- Test 1 – High wind speed (5m/s), stability class D
- Test 2 – Low wind speed (2m/s), stability class F
- Test 3 – Lowest wind speed in model (0.1m/s), stability class D
- Test 4 – Surface roughness (0.5, 0.1 and 1m)
- Test 5 – Release height – comparison between actual release height and ground level release
- Test 6 – Low flow rate release (Phase 2 Emergency 3)
- Test 7 – Inclusion of buildings

6.1.6 For each Test, the predicted concentration at an offsite receptor location has been compared to assess how each model performs. Four receptor locations have been used for each test.

Model Inputs

6.1.7 There are a limited number of dispersion models available on the market within the UK for the modelling of dense gas releases. A review of other assessments was undertaken to determine the models to be considered. An assessment was undertaken by Cambridge Environmental Research Consultants (CERC) on the Essar Oil Project, where ADMS and GASTAR were both used. As this assessment had been completed and submitted, CERC was contacted to determine the best modelling approach for GASTAR (as the publishers of the software).

6.1.8 Following discussions with CERC, the following assumptions were made:

- Use of propane as a representative gas.
- Model the source as a jet, angled upwards, and a thermal release.

6.1.9 This was justified by CERC as "Carbon dioxide is a special case in dense gas dispersion modelling, as it does not exist in the liquid phase at ambient pressures, but instead transfers directly from the solid phase to the gaseous phase (i.e. undergoes sublimation) and vice versa. Dense gas models tend to define their materials in terms of both gas- and liquid- phase physical and chemical properties, and this is the also the case for GASTAR. Therefore, setting up the user-defined parameters for carbon dioxide in GASTAR is not straightforward, could introduce new uncertainties, and requires further investigation. Therefore, for the purposes of these tests, an existing material in GASTAR's material database, propane, was selected to be used as a proxy for CO_2; it has almost the same molecular mass (44.1), and exists in the gas phase over a similar enough temperature range as CO_2 for the purposes of the current scenarios."

6.1.10 The general model conditions used in the assessment are summarised in Table 6-1. Other scenario specific parameters are set out in the following sections.

Table 6-1: General Model Inputs

VARIABLE	ADMS INPUT	GASTAR INPUT
Surface roughness at source	0.3 standard, varied for test	0.3 standard, varied for test
Surface roughness at meteorological site	0.3	
Receptors	Selected discrete receptors (see Table 2-1)	Not Applicable, used results at a similar distance to the source than R2 (i.e. roughly 200m)

Source location	X-Y co-ordinates determined by GIS for the source (Phase 2 Emergency 1) (see Table 2-4)
Emissions	Data provided by BP for Phase 2 Emergency 1 (see Table 2-4)
Sources	See Phase 2 Emergency 1 in Table 2-4
Meteorological data	2F conditions as standard, varied for test
Terrain data	Not Applicable

Sensitivity Results

6.1.11 The results of the sensitivity analysis are presented in Table 6-2.

Table 6-2: Sensitivity Analysis Results - GASTAR vs ADMS 6

TEST ID	SCENARIO DESCRIPTION	PREDICTED CO_2 CONCENTRATION (PPM)		PREDICTED DIFFERENCE (%)
		GASTAR	ADMS 6	
Test 1	5D conditions	Not Grounded at receptor distance (200m)	271 ($R2_m$)	NA
Test 2	2F conditions	Not Grounded at receptor distance (200m)	1114 ($R2_o$)	NA
Test 3	0.1D conditions	19570	107 ($R13_{ay}$)	-99%
Test 4	0.1m roughness	Not Grounded at receptor distance (200m)	1061 ($R2_p$)	NA
	0.3m roughness	Not Grounded at receptor distance (200m)	1114 ($R2_o$)	NA
	1m roughness	Not Grounded at receptor distance (200m)	1143 ($R2_o$)	NA
Test 5	Near Ground Emissions	<0.1	3609 ($R1_{ac}$)	GASTAR unable to model scenario
Test 6	Low Flow	Not Grounded at receptor distance (200m)	1220 ($R13_l$)	NA

Test 7	No Buildings	Not Applicable with Jet sources	308 ($R2_m$)	NA

6.1.12 The sensitivity assessment indicates that AMDS is generally highly sensitive to changes in model set up, with significant changes in predicted concentration based on meteorological conditions and stability classes, and surface roughness. However, the sensitivity tests indicate the GASTAR is generally unable to model dense gas plumes at close range, as the model predicts that the plume does not ground within the same distance, and over such scales does not appear to be highly sensitive to changes in the model set up.

7 APPENDIX C SCENARIO SELECTION

7.1.1 Dispersion modelling has been undertaken for several release scenarios, selected based on anticipated maximum release scenarios in normal operation, start-up/commissioning and emergency scenarios. The process of determining which scenarios should be taken forward to detailed dispersion modelling is set out below.

7.1.2 The pressure, temperature and flowrate parameters used in the gas dispersion modelling (as inputs to ADMS) are based on steady-state conditions in all cases. The dispersion modelling has not considered dynamic changes in the venting process; only initial conditions have been considered, as these are considered to represent conservative scenarios. As such, there is no 'before' and 'after' venting set of conditions that can be provided. The flowrates provided are maximum flowrates estimated based on conditions from the worst-case scenario.

7.1.3 The cases provided in Table 2-2 and Table 2-4 in Section 2, are considered to be critical cases from the environmental impact perspective, selected from current known FEED data, and include the following sources:

- start-up Vent (upstream of CO_2 metering);
- overpressure control downstream of CO_2 separator, upstream of CO_2 compression;
- blocked outlet at CO_2 compression discharge;
- reverse flow from CO_2 pipeline at MAOP (44 barg); and
- commissioning Vent (downstream of CO_2 metering).

7.1.4 The exit velocities provided in Table 2-4 are derived from the volumetric flowrates at atmospheric pressure and exit temperatures at the end of the vent pipe (across the cross-sectional area of the chosen vent pipe size).

7.1.5 The basis for the mass flowrates considered in the dispersion modelling is explained for each case – see narratives provided in Table 7-1 and Table 7-2 below.

7.1.6 All process systems will be provided with monitoring instrumentation, alarms and some with trips. During process upset leading to relief and venting, the Operator will be alerted from the control room and thus take the necessary correction actions upon detection. Typically, this would not be longer than 20 minutes under emergency relieving scenarios. For start-up, venting duration is expected to be within a shift, up to a day. Full flow is assumed as the worst-case scenario.

7.1.7 The given emission rates are based on the current engineering data in FEED (e.g. pressure/temperature/compositions from simulation cases) and assumptions made according to the best knowledge at the current FEED stage.

Table 7-1: Detailed Narrative for Individual Modelled Vent sources

SOURCE ID	TYPE	DESCRIPTION	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMPERATURE (°C)	CO_2 PHASES (DOWNSTREAM)	JUSTIFICATION FOR SCENARIO SELECTION
S1	Commissioning and Start-up	Commissioning & Start-up prior to exporting CO2 to NEP (Initial System Setup and Testing); and Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA Peformance Test) if NEP is unavailable.	21.1	26-36	Gas	During the initial commissioning and startup of the plant the system setup is not complete or tested/verified. The captured CO2 will not meet NEP's required specifications until the system is setup, and the system will lack stability, necessitating the venting of all CO2 to the atmosphere whilst the system undergoes commissioning to meet design specifications. Expected duration (expected intermittent running of the plant for 2 weeks - equivalent of running 2 weeks continous to be deemed credible worst case). Exit velocity calculated based on assumed ID, flowrate and density from HYSYS for downstream of valve. As per the LCHA requirements, the H2T project shall perform the performance test by venting to atmosphere to prove that H2T is ready to commence operations if NEP is

						unavailable to import CO2 (e.g. due to NEP project construction/commissioning delays)
S 2	Operational	Overpressure control downstream of CO2 separator, upstream of CO2 compression.	1.7	35	Gas	This is used as the full flow vent if NEP is offline during operations and grey hydrogen is produced during scenarios described in email. Exit velocity calculated based on assumed ID, flowrate and density from HYSYS for downstream of valve.
S3	Unplanned/ Emergency	Blocked outlet at CO_2 compression discharge.	30	20-25	Gas + Aqueous (99.4/0.06)	Assumed to be full flow relief at system design pressure, at operating temperature of compression system. There is no blowdown case for the CO2 compression system, therefore minimum ambient temperatures do not need to be considered. Downstream conditions estimated in HYSYS. Exit velocity calculated based on assumed ID, flowrate and density from HYSYS for downstream of valve.
Scenario 4	Unplanned/ Emergency	Reverse flow from CO2 pipeline at MAOP (44 barg).	30	-13.5	Gas + Solid (dry ice)	Reverse flow from boundary limit. Minimum ambient conditions (-13.5 degC) considered at pipeline MAOP (44 barg), relieving at 29 barg (system design pressure). Credit taken for dual dissimilar NRVs to reduce flowrate. Case 12 on ROPD. Downstream conditions estimated in HYSYS. Exit velocity calculated

						based on assumed ID, flowrate and vapour density from HYSYS for downstream of valve.

Table 7-2: Modelled Venting Scenarios

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
Scenario 1	1	Start-up Vent (upstream of CO_2 metering)	2	145,000	21.2	26 - 36	Gas	Start for Phase 1 and 2 – Source ID S1
	2	Start-up Vent (upstream of CO_2 metering)	2	145,000	21.2	26 - 36		
Scenario 2	1	Start-up Vent (upstream of CO_2 metering)	2	145,000	21.2	26 - 36		Start up for Phase 1 and operation of Phase 2 – Source ID S1 and S2
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	34	147,000	1.7	35		

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
Scenario 3	1	Start-up Vent (upstream of CO_2 metering)	2	145,000	21.2	26 - 36		Start up of Phase 1 and Emergency release of Phase 2 – Source ID S1 and S3
	2	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 - 25		
Scenario 4	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	2	145,000	1.7	35		Normal operation of Phase 1 and Start up of Phase 2 – Source ID S1 and S2
	2	Start-up Vent (upstream of CO_2 metering)	2	145,000	21.2	26 - 36		
Scenario 5	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	2	145,000	1.7	35		Normal operation of Phase 1 and 2 – Source ID S2

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	34	147,000	1.7	35		
Scenario 6	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	2	145,000	1.7	35		Normal operation of Phase 1 and Emergency of Phase 2 – Source ID S2 and S3
	2	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 - 25		
Scenario 7	1	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 - 25		Emergency of Phase 1 and Start up of Phase 2 – Source ID S3 and S1
	2	Start-up Vent (upstream of CO_2 metering)	2	145,000	21.1	26 - 36		

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
Scenario 8	1	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 - 25		Emergency of Phase 1 and Normal operation of Phase 2 – Source ID S3 and S2
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	34	147,000	1.7	35		
Scenario 9	1	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 - 25		Emergency Scenario for Phases 1 and 2 – blocked CO_2 flow for both Phases and inclusion of closest reverse flow vent to receptors – Source ID S3 and S4
		Reverse flow from CO_2 pipeline at MAOP (44 barg).	-87.5	10,700	30	-13.5		

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
	2	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 - 25		
Scenario 10	1	Commissioning Vent (downstream of CO_2 metering)	2	145,000	21.1	26 - 36		Commissioning – based on Scenario 1. Parameters assumed to be the same as for Start Up.
	2	Commissioning Vent (downstream of CO_2 metering)	2	145,000	21.1	26 - 36		
Scenario 11	1	Commissioning Vent (downstream of CO_2 metering)	2	145,000	21.1	26 - 36		Commissioning – based on Scenario 2. Phase 1 parameters assumed to be the same as for Start Up, Phase 2 in normal operation.
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	34	147,000	1.7	35		

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
Scenario 12	1	Commissioning Vent (downstream of CO_2 metering)	2	145,000	21.1	26 - 36		Commissioning – based on Scenario 3. Phase 1 parameters assumed to be the same as for Start Up, Phase 2 Emergency Scenario.
	2	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 – 25		
Scenario 13	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	2	145,000	1.7	35		Commissioning – based on Scenario 4. Phase 2 parameters assumed to be the same as for Start Up, Phase 1 in normal operation.
	2	Commissioning Vent (downstream of CO_2 metering)	2	145,000	21.1	26 - 36		
Scenario 14	1	Blocked outlet at CO_2 compression discharge.	-18	145,000	30	20 – 25		Commissioning – based on Scenario 7. Phase 2 parameters assumed to be the same as for Start Up, Phase 1 Emergency Scenario.
	2	Commissioning Vent	2	145,000	21.1	26 - 36		

SCENARIO	PHASE	SOURCE DESCRIPTION	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	CO_2 PHASES	JUSTIFICATION FOR SCENARIO SELECTION
		(downstream of CO_2 metering)						