Appendix to report:

SBJ-33-C5-OON-22-RE-016

FATIGUE ASSESSMENT

Appendix title:

Appendix A - Environmental fatigue loads: Lumping of scatter diagrams and realization sensitivity

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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

Norconsult

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Prodtex IFE Pure Logic HEYERDAHL ARKITEKTER AS H&BB MIKO MARINE AS BUKSÉR OG BERGING FORCE TECHNOLOGY SWERIM

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1 INTRODUCTION

In DNV-GL's recommended practice for riser fatigue calculations [1] some guidelines for scatter diagram lumping and time series realizations are provided. Key points can be summarized as follows:

- The damage ratio from each discretized block should not exceed 5-10% of the total damage
- The maximum significant wave height in the block should be used
- The weighted peak wave period should be used, or critical choices if the structure is peak period sensitive.

The guidelines are given for risers, but the principles could be transferred to other structures as well, although some extra investigations should be made.

For risers, DNV-GL indicate that the damage is not sensitive to realizations and that one time series realization per lumped case should be enough. To see if this is the case also for fatigue estimation of the Bjørnafjord floating bridge more investigations are needed.

In this appendix, the lumping of the environmental scatter diagrams is optimized to reduce the number of dynamic response calculations needed to properly estimate the fatigue life. Time series realization sensitivity is also investigated to verify that one realization is enough for fatigue life calculation for this structure.

All investigations in this appendix is performed on the concept model K12-model7 [2], and should be valid also for minor adjustments to the concept.

2 LUMPING OF SCATTER DIAGRAMS

2.1 Wind and wind sea

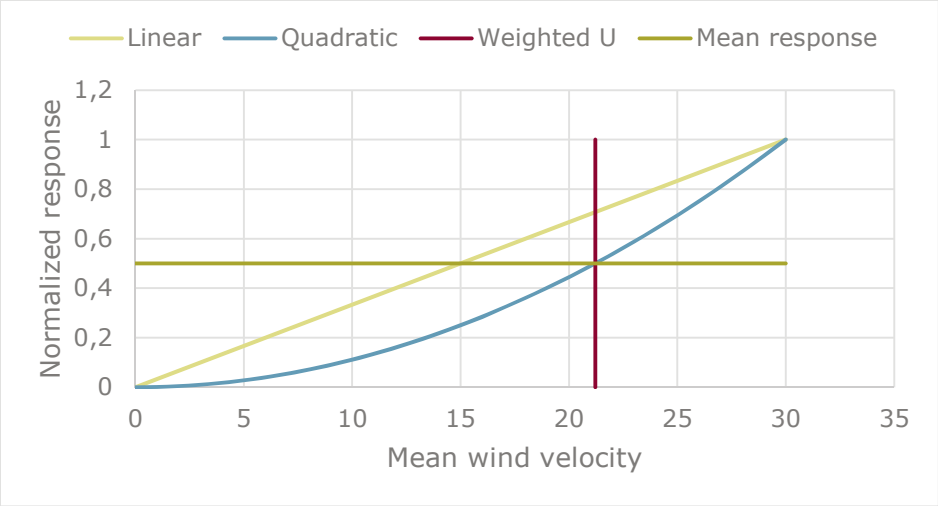
To identify an optimal lumping of the wind sea scatter diagrams, fatigue damage has been calculated for the K12 model 7 version of the Bjørnafjord floating bridge with no lumping of the scatter diagrams. A total of 366 wind sea cases are run. The damage ratio (damage per case divided by total damage) has been calculated for all cases. In this way an optimal lumping of the scatter diagrams can be identified following the guidelines proposed by DNV-GL for riser fatigue calculations [1].

In the following sections a chosen lumping of the scatter diagrams is shown. For all blocks the highest significant wave height is used. If the block ranges over two columns, the highest period is used, and if the block ranges over three blocks the mean period is used. This discretization reduces the number of wind sea cases from 366 to 96 cases.

The wind damage corresponding to the wind sea wave heights is also shown in the following sections. The lumping of the wind cases is corresponding to the lumping of the wind sea scatter diagrams (if the lumped wind sea case range over three wave height rows, then the lumped wind case will also range over three corresponding mean wind velocities according to table 9 in [3]). The mean wind velocity used per lumped case is based on a weighted value over the wind velocity range in the block. The mean wind velocity of a lumped case is calculated as follows:

$$U_{weighted} = U_1 + \frac{U_2 - U_1}{\sqrt{2}}$$

where U_1 is the mean wind velocity at the start of the block, and U_2 is the wind velocity at the end of the block. In this way the mean wind velocity is weighted to give the mean value of a response which is quadratic with respect to mean wind velocity.



> *Figure 1: Weighting of lumped mean wind velocity*

In section 2.1.2 to 2.1.13 the chosen lumping of the wind and wind sea scatter diagrams are shown. In the first figure for each sector the probability density function scatter diagram for

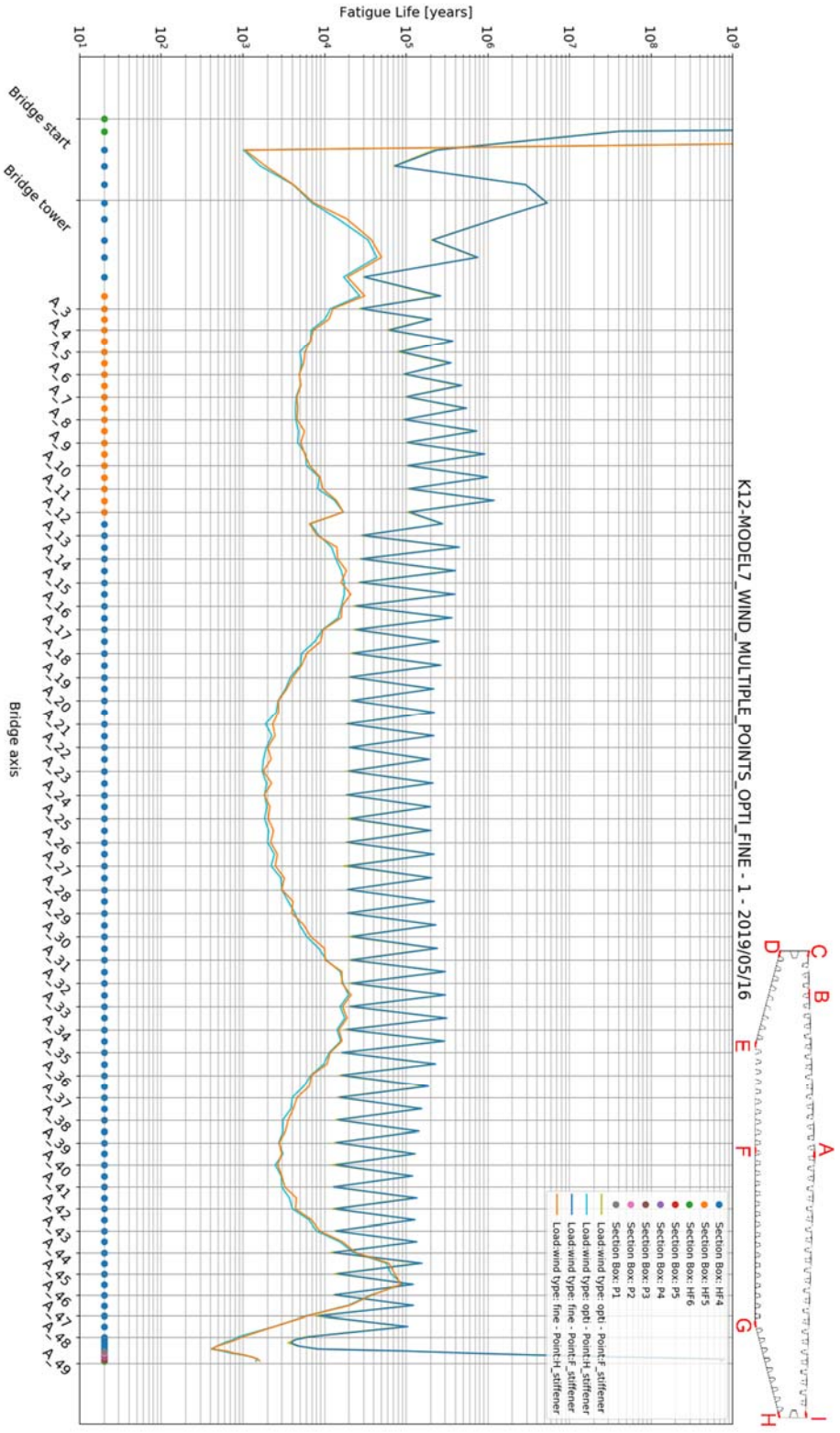
the wind sea sector is shown together with the chosen blocking indicated. In the following figures, damage ratio per case is shown together with indication of the chosen blocking.

Response from sector 7 and 8 dominate the fatigue damage from wind sea in axis 13, and sector 6,7,8 and 11 dominate the fatigue damage from wind sea in axis 47. These axes are chosen to be representative for the worst wind sea response in both bridge ends. Sector 6, 8, 10 and 11 are dominating the damage from wind in axis 27.

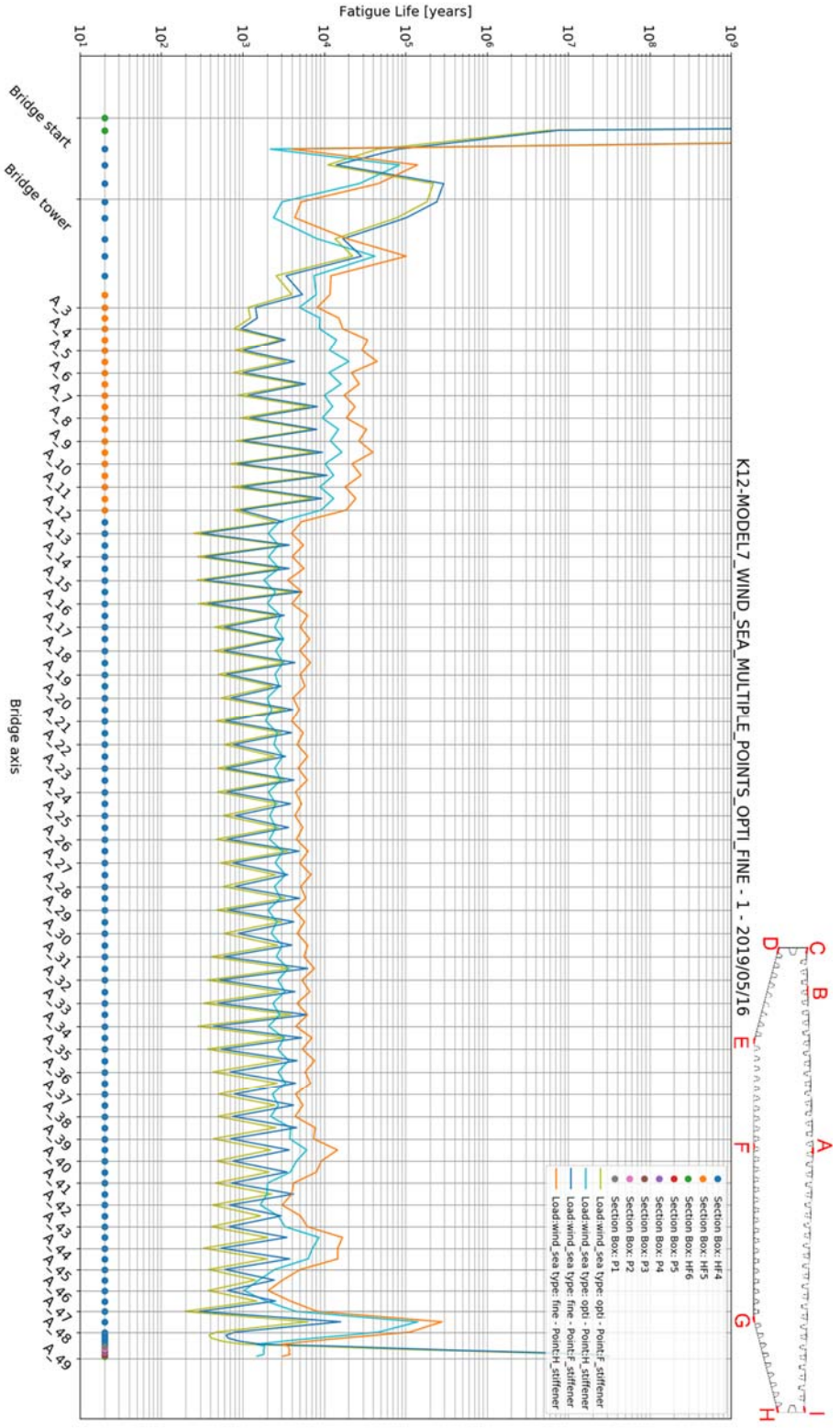
2.1.1 Fatigue life verification of chosen scatter diagram lumping

In Figure 2 and Figure 3 the fatigue life of the F and H stiffeners are shown for the full resolution scatter and the optimized scatter diagram. For wind, a close to perfect match is seen between the optimized scatter and the full resolution, although the optimized resolution is slightly to the conservative side.

For wind sea a good match is found for the F-stiffener, with the optimized resolution slightly on the conservative side. This is expected as the lumped wave height is taken as the maximum in the block in the optimized case. A somewhat less good, but conservative match can be seen for the H-stiffener. The resolution of the wind sea scatter is found by optimization with respect to the F-stiffener since weak axis bending moment is the most important contribution from wind sea.



> *Figure 2: Wind load fatigue life for full resolution (fine) and optimized scatter diagram (opti)*



> *Figure 3: Wind sea fatigue life for full resolution (fine) and optimized scatter diagram (opti)*

2.1.2 Sector 1: 345°-15°

Wind Sea, Scatter diagram: Sector 1: 345° - 15°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			2.72E+00	1.21E-01	1.56E-02								2.85E+00
0.1 - 0.2			6.13E-01	1.50E-01	6.62E-02	1.12E-02							8.41E-01
0.2 - 0.3				2.23E-02	8.19E-03	1.49E-02	5.21E-03						5.06E-02
0.3 - 0.4				1.49E-03	5.21E-03	8.93E-03	2.23E-03	7.44E-04					1.86E-02
0.4 - 0.5					7.44E-04	7.44E-04	5.95E-03	1.49E-03					8.93E-03
0.5 - 0.6						7.44E-04	2.23E-03	7.44E-04					3.72E-03
0.6 - 0.7								1.49E-03					1.49E-03
0.7 - 0.8								1.49E-03					1.49E-03
0.8 - 0.9								2.23E-03	1.49E-03				3.72E-03
0.9 - 1.0													0.00E+00
1.0 - 1.1													0.00E+00
1.1 - 1.2													0.00E+00
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	3.33E+00	2.95E-01	9.60E-02	3.65E-02	1.56E-02	8.19E-03	1.49E-03	0.00E+00	0.00E+00	0.00E+00	3.7842

> *Figure 4: Lumping of wind sea scatter diagram for sector 1*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	2.18E-22	4.90E-13	4.19E-11				
0.15	1.07E-20	1.03E-10	4.87E-08	5.28E-07			
0.25		1.94E-10	7.54E-08	7.53E-06	9.00E-06		
0.35		7.38E-11	3.07E-07	3.08E-05	2.26E-05		
0.45					1.84E-04	1.09E-04	
0.55					1.89E-04		
0.65						6.23E-04	
0.75						1.11E-03	
0.85						3.12E-03	3.35E-03
0.95							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	1.68E-22	1.32E-13	3.50E-11				
0.15	6.32E-21	3.81E-11	3.91E-08	5.07E-07			
0.25		8.26E-11	5.13E-08	1.05E-05	1.81E-05		
0.35		3.22E-11	1.51E-07	2.66E-05	4.38E-05		
0.45					3.39E-04	1.97E-04	
0.55					4.15E-04		
0.65						1.17E-03	
0.75						2.45E-03	
0.85						5.07E-03	3.30E-03
0.95							

V10	Damageratio
2.12	8.30E-10
2.73	4.87E-09
5.15	2.84E-07
6.28	1.09E-06
7.44	3.04E-06
8.67	8.58E-06
11.43	3.23E-05
10.78	4.72E-05
12.86	6.11E-04

> *Figure 5: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 1*

2.1.3 Sector 2: 15°-45°

Wind Sea, Scatter diagram: Sector 2: 15° - 45°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			2.13E+00	7.67E-02	2.98E-03								2.21E+00
0.1 - 0.2			8.17E-01	7.81E-02	5.13E-02	3.72E-03							9.50E-01
0.2 - 0.3				5.21E-03	7.44E-03	7.44E-03	1.49E-03						2.16E-02
0.3 - 0.4				2.98E-03	4.47E-03	3.72E-03	1.49E-03						1.27E-02
0.4 - 0.5							3.72E-03						3.72E-03
0.5 - 0.6							7.44E-04						7.44E-04
0.6 - 0.7													0.00E+00
0.7 - 0.8													0.00E+00
0.8 - 0.9													0.00E+00
0.9 - 1.0													0.00E+00
1.0 - 1.1													0.00E+00
1.1 - 1.2													0.00E+00
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	2.94E+00	1.63E-01	6.62E-02	1.49E-02	7.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.1983

> *Figure 6: Lumping of wind sea scatter diagram for sector 2*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	2.26E-22	3.23E-13	1.33E-11				
0.15	1.99E-20	6.76E-11	5.66E-08	2.77E-07			
0.25		6.36E-11	1.03E-07	6.61E-06	3.41E-06		
0.35		2.01E-10	4.22E-07	1.95E-05	1.86E-05		
0.45					2.02E-04		
0.55							
0.65							
0.75							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	3.41E-23	2.79E-14	1.65E-12				
0.15	2.87E-21	8.00E-12	7.28E-09	3.73E-08			
0.25		6.01E-12	1.17E-08	1.14E-06	1.08E-06		
0.35		2.37E-11	4.64E-08	3.13E-06	5.65E-06		
0.45					4.89E-05		
0.55							
0.65							
0.75							

V10	Damageratio
2.14	6.01E-10
2.49	1.14E-09
4.93	1.31E-07
5.95	2.80E-07
8.64	4.21E-06

> *Figure 7: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 2*

2.1.4 Sector 3: 45°-75°

Wind Sea, Scatter diagram: Sector 3: 45° - 75°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			1.19E+00	1.92E-01	2.31E-02								1.41E+00
0.1 - 0.2			7.56E-01	6.47E-01	2.89E-01	1.93E-02							1.71E+00
0.2 - 0.3				7.07E-02	2.78E-01	7.00E-02	2.98E-03						4.22E-01
0.3 - 0.4					6.33E-02	7.89E-02	1.27E-02						1.55E-01
0.4 - 0.5						2.83E-02	8.93E-03						3.72E-02
0.5 - 0.6						5.21E-03	1.64E-02						2.16E-02
0.6 - 0.7							1.49E-03	1.49E-03					2.98E-03
0.7 - 0.8													0.00E+00
0.8 - 0.9													0.00E+00
0.9 - 1.0													0.00E+00
1.0 - 1.1													0.00E+00
1.1 - 1.2													0.00E+00
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	1.95E+00	9.10E-01	6.53E-01	2.02E-01	4.24E-02	1.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.7574

> *Figure 8: Lumping of wind sea scatter diagram for sector 3*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	2.38E-23	2.26E-13	1.63E-11				
0.15	3.53E-21	1.84E-10	6.57E-08	1.31E-07			
0.25		3.09E-10	6.90E-07	6.77E-06	7.53E-07		
0.35			8.48E-07	4.95E-05	1.58E-05		
0.45				4.88E-05	4.33E-05		
0.55				2.12E-05	1.99E-04		
0.65					4.46E-05	9.42E-05	
0.75							
0.85							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	1.06E-24	4.78E-15	3.68E-13				
0.15	1.51E-22	3.27E-12	1.19E-09	5.87E-09			
0.25		4.44E-12	1.60E-08	3.83E-07	8.06E-08		
0.35			1.59E-08	2.10E-06	1.50E-06		
0.45				3.21E-06	3.00E-06		
0.55				1.41E-06	1.78E-05		
0.65					3.42E-06	6.72E-06	
0.75							
0.85							

V10	Damageratio
2.39	1.67E-09
3.25	4.83E-08
4.72	1.84E-06
6.04	8.30E-06
7.2	1.35E-05
8.19	4.84E-05
9.7	3.14E-05

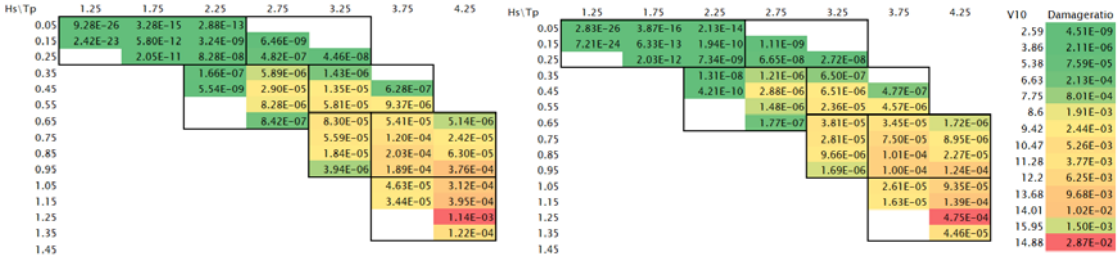
> *Figure 9: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 3*

2.1.5 Sector 4: 75°-105°

Wind Sea, Scatter diagram: Sector 4: 75° - 105°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.5 - 6.0	Sum
0.0 - 0.1			1.08E+00	3.85E-01	2.68E-02							1.49E+00
0.1 - 0.2			1.23E+00	2.95E+00	9.89E-01	5.88E-02						5.23E+00
0.2 - 0.3				6.11E-01	2.54E+00	3.50E-01	1.56E-02					3.52E+00
0.3 - 0.4					8.19E-01	9.98E-01	7.59E-02					1.89E+00
0.4 - 0.5					8.19E-03	7.17E-01	2.20E-01	5.21E-03				9.50E-01
0.5 - 0.6						1.35E-01	3.26E-01	2.23E-02				4.84E-01
0.6 - 0.7						5.95E-03	2.04E-01	5.51E-02	2.23E-03			2.67E-01
0.7 - 0.8							7.00E-02	7.22E-02	5.95E-03			1.48E-01
0.8 - 0.9							1.27E-02	6.10E-02	8.19E-03			8.19E-02
0.9 - 1.0							1.49E-03	3.13E-02	2.23E-02			5.51E-02
1.0 - 1.1								5.21E-03	1.19E-02			1.71E-02
1.1 - 1.2								2.23E-03	1.04E-02			1.27E-02
1.2 - 1.3									1.86E-02	7.44E-04		1.93E-02
1.3 - 1.4									1.49E-03	2.98E-03		4.47E-03
1.4 - 1.5										3.72E-03		3.72E-03
1.5 - 1.6										5.21E-03		5.21E-03
1.6 - 1.7												0.00E+00
1.7 - 1.8												0.00E+00
1.8 - 1.9												0.00E+00
1.9 - 2.0												0.00E+00
Sum	0.00E+00	0.00E+00	2.31E+00	3.94E+00	4.38E+00	2.27E+00	9.25E-01	2.55E-01	8.11E-02	1.27E-02	0.00E+00	0.00E+00	14.1754

> *Figure 10: Lumping of wind sea scatter diagram for sector 4*



> *Figure 11: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 4*

2.1.6 Sector 5: 105°-135°

Wind Sea, Scatter diagram: Sector 5: 105° - 135°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			1.09E+00	2.68E-01	6.70E-03								1.38E+00
0.1 - 0.2			1.06E+00	1.43E+00	4.41E-01	8.93E-03							2.94E+00
0.2 - 0.3				4.68E-01	8.59E-01	1.69E-01	2.23E-03	7.44E-04					1.50E+00
0.3 - 0.4				2.23E-03	4.27E-01	4.12E-01	1.93E-02						8.61E-01
0.4 - 0.5					4.61E-02	2.81E-01	7.00E-02	7.44E-04					3.98E-01
0.5 - 0.6						9.82E-02	9.00E-02	7.44E-03					1.96E-01
0.6 - 0.7						1.19E-02	6.33E-02	2.98E-03	1.49E-03				7.96E-02
0.7 - 0.8							4.24E-02	1.71E-02	1.49E-03				6.10E-02
0.8 - 0.9							1.27E-02	1.93E-02	3.72E-03				3.57E-02
0.9 - 1.0							2.23E-03	9.67E-03	1.49E-03				1.34E-02
1.0 - 1.1								1.49E-03	6.70E-03				8.19E-03
1.1 - 1.2									7.44E-04				7.44E-04
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	2.15E+00	2.16E+00	1.78E+00	9.82E-01	3.02E-01	5.95E-02	1.56E-02	0.00E+00	0.00E+00	0.00E+00	7.4561

> *Figure 12: Lumping of wind sea scatter diagram for sector 5*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	3.61E-26	1.16E-15	2.11E-14				
0.15	6.43E-24	1.32E-12	3.83E-10	4.25E-10			
0.25		5.44E-12	1.15E-08	9.98E-08	4.94E-09		
0.35		1.24E-13	3.13E-08	1.14E-06	2.42E-07		
0.45			1.11E-08	4.21E-06	3.16E-06		
0.55				3.82E-06	1.05E-05	1.93E-06	
0.65				8.68E-07	1.64E-05	1.52E-06	1.93E-06
0.75					1.74E-05	2.54E-05	4.60E-06
0.85					1.10E-05	4.33E-05	1.54E-05
0.95					3.67E-06	3.33E-05	8.74E-06
1.05						9.29E-06	1.04E-04
1.15							
1.25							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	1.21E-24	1.72E-14	3.83E-13				
0.15	2.78E-22	2.50E-11	5.72E-09	8.64E-09			
0.25		9.71E-11	1.72E-07	2.65E-06	1.32E-07		
0.35		2.39E-12	3.89E-07	3.29E-05	7.77E-06		
0.45			1.32E-07	7.69E-05	8.64E-05		
0.55				7.84E-05	3.70E-04	9.46E-05	
0.65				1.90E-05	5.06E-04	1.02E-04	4.89E-05
0.75					8.79E-04	1.27E-03	1.55E-04
0.85					4.99E-04	2.43E-03	5.39E-04
0.95					1.50E-04	1.72E-03	3.65E-04
1.05						5.39E-04	2.61E-03
1.15							
1.25							

V10	Damageratio
2.49	3.15E-09
3.93	1.99E-06
5.7	3.46E-05
7.17	3.98E-04
8.53	1.17E-03
10.03	3.13E-03
10.95	5.89E-03
12.1	4.20E-03
12.73	1.07E-02
14.01	1.46E-02
14.27	4.54E-03

> *Figure 13: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 5*

2.1.7 Sector 6: 135°-165°

Wind Sea, Scatter diagram: Sector 6: 135° - 165°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			1.80E+00	1.53E-01	2.23E-03								1.95E+00
0.1 - 0.2			1.11E+00	1.42E+00	2.02E-01	2.23E-02							2.75E+00
0.2 - 0.3				1.29E+00	6.87E-01	1.03E-01	7.44E-03						2.08E+00
0.3 - 0.4				8.19E-02	1.44E+00	1.59E-01	2.68E-02	7.44E-04	7.44E-04				1.71E+00
0.4 - 0.5					6.17E-01	4.35E-01	2.01E-02						1.07E+00
0.5 - 0.6					4.61E-02	5.31E-01	3.94E-02	1.49E-03	7.44E-04				6.18E-01
0.6 - 0.7						2.08E-01	5.58E-02	4.47E-03	7.44E-04				2.69E-01
0.7 - 0.8						3.05E-02	8.71E-02	2.23E-03					1.20E-01
0.8 - 0.9						1.49E-03	6.77E-02	2.98E-03					7.22E-02
0.9 - 1.0							7.44E-03	9.67E-03					1.71E-02
1.0 - 1.1								2.23E-03					2.23E-03
1.1 - 1.2								7.44E-04					7.44E-04
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	2.91E+00	2.94E+00	3.00E+00	1.49E+00	3.12E-01	2.46E-02	2.23E-03	0.00E+00	0.00E+00	0.00E+00	10.6739

> *Figure 14: Lumping of wind sea scatter diagram for sector 6*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	3.87E-24	1.62E-14	1.76E-13				
0.15	6.51E-22	3.71E-11	7.44E-09	4.32E-08			
0.25		3.50E-10	2.95E-07	3.24E-06	6.84E-07		
0.35		1.17E-10	3.44E-06	2.45E-05	1.14E-05		
0.45			5.83E-06	2.15E-04	3.65E-05		
0.55			1.12E-06	7.62E-04	2.03E-04	2.02E-05	
0.65				9.22E-04	7.01E-04	1.25E-04	
0.75				1.66E-04	2.08E-03	1.11E-04	
0.85				1.61E-05	2.04E-03	3.23E-04	
0.95					4.76E-04	1.88E-03	
1.05						8.86E-04	
1.15							
1.25							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	4.84E-23	2.28E-13	1.64E-12				
0.15	6.44E-21	5.43E-10	4.18E-08	5.11E-07			
0.25		5.47E-09	2.09E-06	2.14E-05	1.60E-05		
0.35		1.66E-09	2.06E-05	2.15E-04	2.63E-04		
0.45			3.50E-05	2.08E-03	6.47E-04		
0.55			7.40E-06	6.17E-03	2.75E-03	3.08E-04	
0.65				7.38E-03	1.48E-02	1.92E-03	
0.75				1.77E-03	3.63E-02	2.25E-03	
0.85				1.42E-04	5.30E-02	4.95E-03	
0.95					1.03E-02	2.04E-02	
1.05						7.75E-03	
1.15							
1.25							

V10	Damageratio
2.35	1.22E-09
4.06	1.32E-06
6.06	1.50E-04
7.44	9.19E-04
8.94	4.40E-03
10.47	1.16E-02
11.79	2.37E-02
13.33	4.46E-02
14.16	3.02E-02
14.66	1.71E-02
16.43	3.69E-03

> *Figure 15: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 6*

2.1.8 Sector 7: 165°-195°

Wind Sea, Scatter diagram: Sector 7: 165° - 195°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			3.07E+00	1.96E-01	2.98E-03	7.44E-04							3.27E+00
0.1 - 0.2			1.11E+00	8.54E-01	3.86E-01	6.62E-02	7.44E-04						2.42E+00
0.2 - 0.3				4.35E-01	4.49E-01	2.39E-01	1.34E-02	1.49E-03	7.44E-04				1.14E+00
0.3 - 0.4				3.42E-02	4.40E-01	2.86E-01	6.33E-02	2.98E-03					8.26E-01
0.4 - 0.5					2.05E-01	2.42E-01	1.14E-01	2.23E-03					5.63E-01
0.5 - 0.6					2.98E-02	1.73E-01	1.09E-01	8.19E-03					3.20E-01
0.6 - 0.7						1.09E-01	5.88E-02	2.98E-02					1.98E-01
0.7 - 0.8						3.42E-02	2.75E-02	1.64E-02					7.81E-02
0.8 - 0.9						6.70E-03	2.16E-02	1.41E-02	7.44E-04				4.32E-02
0.9 - 1.0							2.98E-03	6.70E-03	7.44E-04				1.04E-02
1.0 - 1.1								7.44E-04					7.44E-04
1.1 - 1.2													0.00E+00
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	4.18E+00	1.52E+00	1.51E+00	1.16E+00	4.12E-01	8.26E-02	2.23E-03	0.00E+00	0.00E+00	0.00E+00	8.8641

> *Figure 16: Lumping of wind sea scatter diagram for sector 7*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	2.17E-22	4.65E-13	8.27E-12				
0.15	2.47E-20	5.12E-10	3.34E-07	3.24E-06			
0.25	0.00E+00	4.39E-09	4.81E-06	1.29E-04	2.70E-05	5.96E-06	
0.35		1.46E-09	2.06E-05	8.87E-04	6.90E-04	5.52E-05	
0.45			3.88E-05	2.64E-03	4.46E-03	1.31E-04	
0.55			1.52E-05	5.72E-03	9.31E-03	1.39E-03	
0.65				6.49E-03	1.40E-02	1.14E-02	
0.75				5.15E-03	1.09E-02	1.28E-02	
0.85				1.81E-03	1.52E-02	1.76E-02	
0.95					3.20E-03	1.23E-02	
1.05							
1.15							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	1.74E-22	3.02E-13	6.28E-12				
0.15	1.51E-20	2.50E-10	1.99E-07	3.42E-06			
0.25		1.51E-09	2.89E-06	1.46E-04	4.44E-05	9.60E-06	
0.35		8.01E-10	1.47E-05	1.00E-03	1.09E-03	1.05E-04	
0.45			2.12E-05	2.52E-03	6.70E-03	3.17E-04	
0.55			1.29E-05	6.06E-03	1.97E-02	3.16E-03	
0.65				8.70E-03	2.15E-02	2.41E-02	
0.75				4.43E-03	1.99E-02	2.71E-02	
0.85				1.85E-03	2.98E-02	3.56E-02	
0.95					5.16E-03	2.26E-02	
1.05							
1.15							

V10	Damageratio
2.11	8.34E-10
3.61	2.04E-07
5.63	9.93E-06
6.91	1.65E-04
8.33	5.13E-04
9.77	2.32E-03
11.01	7.50E-03
12.65	9.00E-03
13.79	1.53E-02
14.4	4.29E-03

> *Figure 17: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 7*

2.1.9 Sector 8: 195°-225°

Wind Sea, Scatter diagram: Sector 8: 195° - 225°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			2.38E+00	1.73E-01	6.70E-03								2.56E+00
0.1 - 0.2			1.26E+00	2.59E+00	5.78E-01	6.55E-02	1.49E-03						4.49E+00
0.2 - 0.3				9.12E-01	2.21E+00	3.20E-01	7.44E-03						3.45E+00
0.3 - 0.4				7.44E-04	1.37E+00	8.82E-01	4.02E-02	7.44E-04					2.30E+00
0.4 - 0.5					4.61E-02	1.18E+00	1.41E-01	1.49E-03					1.37E+00
0.5 - 0.6						3.71E-01	3.77E-01	4.47E-03					7.52E-01
0.6 - 0.7						2.31E-02	4.17E-01	2.90E-02					4.69E-01
0.7 - 0.8							1.49E-01	9.00E-02					2.39E-01
0.8 - 0.9							1.71E-02	1.14E-01	1.49E-03				1.32E-01
0.9 - 1.0							7.44E-04	3.42E-02	3.72E-03				3.87E-02
1.0 - 1.1								4.47E-03	7.44E-03				1.19E-02
1.1 - 1.2								7.44E-04	1.49E-03				2.23E-03
1.2 - 1.3									7.44E-04				7.44E-04
1.3 - 1.4									7.44E-04				7.44E-04
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	3.64E+00	3.67E+00	4.21E+00	2.84E+00	1.15E+00	2.79E-01	1.56E-02	0.00E+00	0.00E+00	0.00E+00	15.8163

> *Figure 18: Lumping of wind sea scatter diagram for sector 8*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	2.98E-22	1.03E-12	4.50E-11				
0.15	4.79E-20	2.49E-09	6.62E-07	4.70E-06	3.04E-07		
0.25		1.11E-08	4.03E-05	2.82E-04	1.57E-05		
0.35			1.09E-04	4.60E-03	4.38E-04		
0.45			2.91E-05	1.98E-02	5.85E-03	1.41E-04	
0.55				1.83E-02	4.80E-02	1.04E-03	
0.65				2.18E-03	1.16E-01	1.60E-02	
0.75					7.45E-02	9.30E-02	
0.85					1.57E-02	2.15E-01	4.10E-03
0.95						9.24E-02	1.58E-02
1.05						1.72E-02	4.05E-02
1.15							1.19E-02
1.25							

Hs\Tp	1_25	1_75	2_25	2_75	3_25	3_75	4_25
0.05	3.14E-23	8.25E-14	3.72E-12				
0.15	5.19E-21	3.39E-10	7.09E-08	7.36E-07	6.95E-08		
0.25		1.31E-09	4.06E-06	4.59E-05	6.47E-06		
0.35			1.12E-05	7.00E-04	1.76E-04		
0.45			1.96E-06	3.12E-03	1.92E-03	4.39E-05	
0.55				2.72E-03	1.26E-02	3.72E-04	
0.65				4.31E-04	3.87E-02	5.82E-03	
0.75					3.11E-02	3.15E-02	
0.85					5.26E-03	7.78E-02	9.89E-04
0.95						3.29E-02	3.46E-03
1.05						6.85E-03	1.22E-02
1.15							2.96E-03
1.25							

V10	Damageratio
2.18	1.85E-09
3.82	9.45E-07
5.64	5.86E-05
7	5.99E-04
8.52	1.24E-03
9.81	5.02E-03
11.47	2.13E-02
12.62	2.01E-02
14.02	5.35E-02
14.94	2.75E-02
16.08	9.70E-03
19.57	1.08E-02

> *Figure 19: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 8*

2.1.10 Sector 9: 225°-255°

Wind Sea, Scatter diagram: Sector 9: 225° - 255°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			1.25E+00	9.75E-02	7.44E-04								1.35E+00
0.1 - 0.2			6.59E-01	8.25E-01	1.79E-02								1.50E+00
0.2 - 0.3				5.03E-01	3.36E-01		7.44E-04						8.39E-01
0.3 - 0.4				3.72E-03	5.52E-01	1.56E-02							5.72E-01
0.4 - 0.5					1.67E-01	2.32E-01							4.00E-01
0.5 - 0.6						1.97E-01	1.49E-03						1.99E-01
0.6 - 0.7						9.23E-02	2.23E-02						1.15E-01
0.7 - 0.8						8.93E-03	5.80E-02						6.70E-02
0.8 - 0.9							3.13E-02						3.13E-02
0.9 - 1.0							1.41E-02	7.44E-04					1.49E-02
1.0 - 1.1							3.72E-03						3.72E-03
1.1 - 1.2							7.44E-04	7.44E-04					1.49E-03
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	1.91E+00	1.43E+00	1.07E+00	5.46E-01	1.32E-01	1.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.0932

> *Figure 20: Lumping of wind sea scatter diagram for sector 9*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	2.42E-23	1.01E-13					
0.15	3.37E-21	2.31E-10	2.78E-09				
0.25		2.34E-09	7.92E-07				
0.35		6.91E-11	6.36E-06	7.40E-06			
0.45			9.86E-06	4.51E-04			
0.55				1.20E-03	2.12E-05		
0.65				1.05E-03	6.84E-04		
0.75				2.52E-04	4.34E-03		
0.85					3.81E-03		
0.95					3.02E-03		
1.05					1.14E-03		
1.15							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	1.03E-24	1.62E-15					
0.15	1.32E-22	4.47E-12	6.38E-11				
0.25		3.13E-11	1.89E-08				
0.35		1.20E-12	1.64E-07	3.95E-07			
0.45			1.71E-07	2.33E-05			
0.55				4.53E-05	1.51E-06		
0.65				5.12E-05	6.39E-05		
0.75				9.64E-06	2.79E-04		
0.85					2.64E-04		
0.95					2.14E-04		
1.05					9.89E-05		
1.15							

V10	Damageratio
2.21	9.91E-10
3.96	3.81E-07
6.07	4.72E-05
7.66	3.09E-04
8.93	1.26E-03
10.44	3.83E-03
11.83	1.06E-02
13.44	1.63E-02
14.41	2.01E-02
15.26	1.42E-02
17.22	2.14E-03
16.11	1.31E-02

> *Figure 21: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 9*

2.1.11 Sector 10: 255°-285°

Wind Sea, Scatter diagram: Sector 10: 255° - 285°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			1.17E+00	1.38E-01	8.93E-03								1.31E+00
0.1 - 0.2			5.77E-01	1.25E+00	9.00E-02	5.21E-03							1.92E+00
0.2 - 0.3				3.39E-01	4.15E-01	8.19E-03							7.63E-01
0.3 - 0.4				1.49E-03	4.17E-01	8.04E-02							4.99E-01
0.4 - 0.5					1.06E-01	2.62E-01	2.23E-03						3.71E-01
0.5 - 0.6						1.96E-01	1.34E-02						2.10E-01
0.6 - 0.7						7.89E-02	5.73E-02						1.36E-01
0.7 - 0.8						6.70E-03	7.52E-02	7.44E-04					8.26E-02
0.8 - 0.9						7.44E-04	5.13E-02	2.98E-03					5.51E-02
0.9 - 1.0							2.98E-02	1.56E-02					4.54E-02
1.0 - 1.1							8.19E-03	1.12E-02					1.93E-02
1.1 - 1.2								8.93E-03					8.93E-03
1.2 - 1.3								2.23E-03	7.44E-04				2.98E-03
1.3 - 1.4								1.49E-03	7.44E-04				2.23E-03
1.4 - 1.5								7.44E-04	7.44E-04				1.49E-03
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	1.74E+00	1.73E+00	1.04E+00	6.39E-01	2.37E-01	4.39E-02	2.23E-03	0.00E+00	0.00E+00	0.00E+00	5.4326

> *Figure 22: Lumping of wind sea scatter diagram for sector 10*

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	1.14E-25	1.22E-15	1.00E-13				
0.15	1.23E-23	2.65E-12	2.95E-10	5.21E-10			
0.25		8.11E-12	1.23E-08	1.17E-08			
0.35		2.50E-13	8.45E-08	6.00E-07			
0.45			6.16E-08	6.12E-06	1.33E-07		
0.55				1.48E-05	2.26E-06		
0.65				1.05E-05	1.86E-05		
0.75				2.15E-06	6.54E-05		
0.85					7.02E-05	9.34E-06	
0.95					7.07E-05	9.77E-05	
1.05					3.96E-05	1.16E-04	
1.15						1.42E-04	
1.25						5.74E-05	
1.35						5.24E-05	
1.45							

Hs\Tp	1.25	1.75	2.25	2.75	3.25	3.75	4.25
0.05	3.00E-26	1.37E-16	1.03E-14				
0.15	3.65E-24	2.95E-13	2.58E-11	8.30E-11			
0.25		1.06E-12	1.32E-09	1.93E-09			
0.35		2.53E-14	5.73E-09	8.68E-08			
0.45			5.52E-09	9.40E-07	7.60E-08		
0.55				1.74E-06	8.63E-07		
0.65				1.98E-06	1.02E-05		
0.75				3.93E-07	2.78E-05		
0.85					3.30E-05	5.56E-06	
0.95					3.71E-05	5.31E-05	
1.05					1.87E-05	6.96E-05	
1.15						8.57E-05	
1.25						3.92E-05	
1.35						3.20E-05	
1.45							

V10	Damageratio
2.19	9.00E-10
3.89	5.09E-07
5.59	1.68E-05
7.11	1.64E-04
8.27	8.05E-04
9.59	1.24E-03
10.85	3.09E-03
12.19	1.57E-02
13.59	1.97E-02
14.71	4.56E-02
16.33	4.96E-02
16.83	2.64E-02
20.18	4.98E-03
21.05	2.55E-02
17.48	2.47E-02

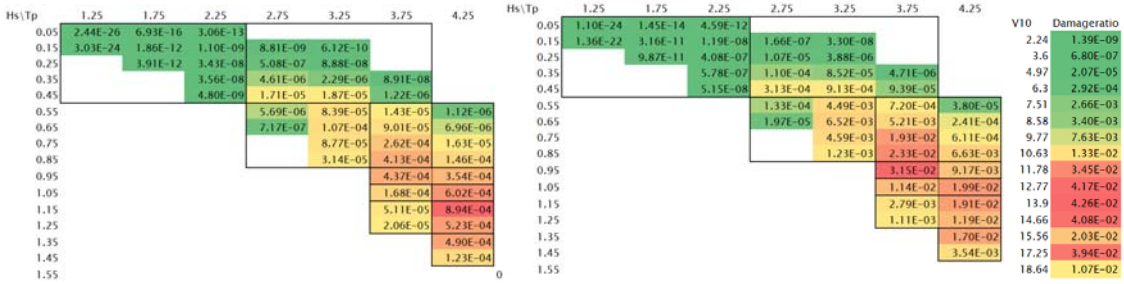
> *Figure 23: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 10*

2.1.12 Sector 11: 285°-315°

Wind Sea, Scatter diagram: Sector 11: 285° - 315°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			9.46E-01	2.53E-01	7.44E-02								1.27E+00
0.1 - 0.2			5.47E-01	2.08E+00	1.12E+00	1.64E-01	3.72E-03						3.92E+00
0.2 - 0.3				4.74E-01	2.24E+00	7.15E-01	3.65E-02						3.46E+00
0.3 - 0.4					7.33E-01	1.55E+00	1.85E-01	3.72E-03					2.47E+00
0.4 - 0.5					1.64E-02	1.15E+00	5.40E-01	1.79E-02					1.72E+00
0.5 - 0.6						1.86E-01	9.05E-01	5.80E-02	2.23E-03				1.15E+00
0.6 - 0.7						9.67E-03	5.48E-01	1.53E-01	5.95E-03				7.16E-01
0.7 - 0.8							2.15E-01	2.86E-01	6.70E-03				5.08E-01
0.8 - 0.9							3.42E-02	2.30E-01	3.27E-02				2.97E-01
0.9 - 1.0							7.44E-04	1.39E-01	4.09E-02				1.81E-01
1.0 - 1.1								3.27E-02	5.13E-02				8.41E-02
1.1 - 1.2								5.95E-03	3.20E-02	7.44E-04			3.87E-02
1.2 - 1.3								1.49E-03	1.41E-02	1.49E-03			1.71E-02
1.3 - 1.4									1.19E-02	2.98E-03			1.49E-02
1.4 - 1.5									2.23E-03	2.98E-03			5.21E-03
1.5 - 1.6										1.49E-03			1.49E-03
1.6 - 1.7										2.98E-03			2.98E-03
1.7 - 1.8										7.44E-04			7.44E-04
1.8 - 1.9										7.44E-04	7.44E-04		1.49E-03
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	1.49E+00	2.81E+00	4.18E+00	3.77E+00	2.47E+00	9.27E-01	2.00E-01	1.41E-02	7.44E-04	0.00E+00	15.8862

> *Figure 24: Lumping of wind sea scatter diagram for sector 11*



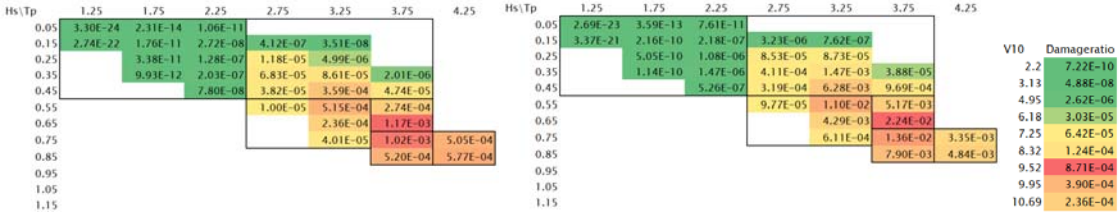
> *Figure 25: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 11*

2.1.13 Sector 12: 315°-345°

Wind Sea, Scatter diagram: Sector 12: 315° - 345°

Hm0 [m] \ Tp [s]	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	Sum
0.0 - 0.1			1.36E+00	2.42E-01	8.56E-02								1.69E+00
0.1 - 0.2			5.34E-01	6.63E-01	8.82E-01	1.88E-01	4.47E-03						2.27E+00
0.2 - 0.3				1.18E-01	3.36E-01	3.74E-01	4.84E-02	7.44E-04					8.77E-01
0.3 - 0.4				5.21E-03	8.78E-02	3.19E-01	1.45E-01	1.49E-03					5.58E-01
0.4 - 0.5					7.44E-03	6.70E-02	1.82E-01	1.04E-02					2.66E-01
0.5 - 0.6						7.44E-03	9.45E-02	2.38E-02	7.44E-04				1.27E-01
0.6 - 0.7							2.23E-02	4.61E-02	7.44E-04				6.92E-02
0.7 - 0.8							1.49E-03	1.64E-02	2.98E-03				2.08E-02
0.8 - 0.9								4.47E-03	2.98E-03				7.44E-03
0.9 - 1.0													0.00E+00
1.0 - 1.1													0.00E+00
1.1 - 1.2													0.00E+00
1.2 - 1.3													0.00E+00
1.3 - 1.4													0.00E+00
1.4 - 1.5													0.00E+00
1.5 - 1.6													0.00E+00
1.6 - 1.7													0.00E+00
1.7 - 1.8													0.00E+00
1.8 - 1.9													0.00E+00
1.9 - 2.0													0.00E+00
Sum	0.00E+00	0.00E+00	1.89E+00	1.03E+00	1.40E+00	9.55E-01	4.98E-01	1.03E-01	7.44E-03	0.00E+00	0.00E+00	0.00E+00	5.8843

> *Figure 26: Lumping of wind sea scatter diagram for sector 12*



> *Figure 27: Wind sea damage ratio per case for axis 13 (left) and axis 47 (middle) and wind damage ratio per case for axis 27 (right) for sector 12*

2.2 Swell

The damage ratio per case has been calculated for a fine resolution of the swell scatter diagram to identify an optimal lumping of the cases. The fine resolution is not a full resolution on the Hs-axis for the swell cases but has a constant lumping of 0,03 m. As shown in Figure 29 this resolution is too coarse in some areas, so the resulting optimized lumping is more accurate than the one referred to as fine in the following figures.

The chosen lumping is shown in Figure 28 and the resulting lumped damage ratios are shown in Figure 30.

In Figure 31 the "fine" resolution fatigue damage is compared with the optimized resolution. The optimized resolution give a shorter fatigue life than the "fine" resolution, indicating that the "fine" resolution was too coarse.

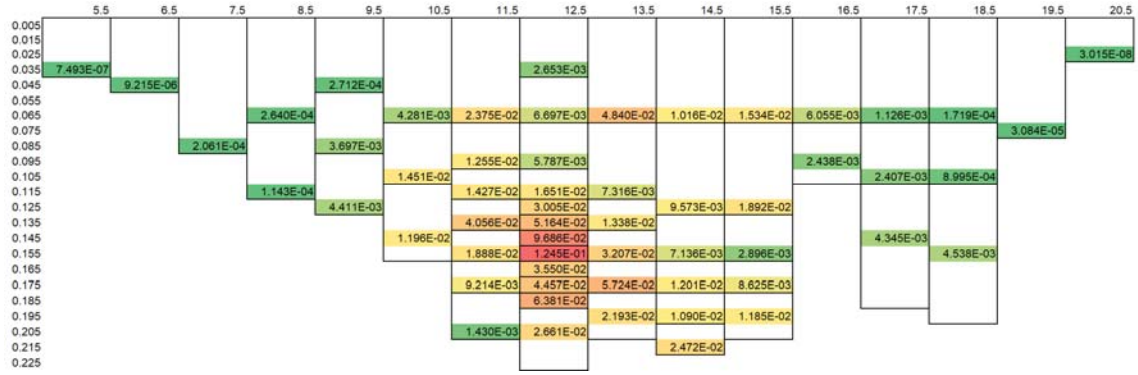
Swell, Scatter diagram, All Year

	Hm0	Tp <2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 -19	19 - 20	>20	Sum
0.00	0.01	60.9633				1.6344	1.4060	1.1692	1.4633	1.5049	1.4448	1.1229	0.6123	0.3330	0.1545	0.0990	0.0351	0.0139	0.0037			71.9603
0.01	0.02					0.5291	1.2987	0.9278	1.1238	1.1127	0.9925	0.8491	0.7825	0.5291	0.3043	0.1609	0.0647	0.0277	0.0111		0.0018	8.7160
0.02	0.03					0.0990	0.3894	0.7853	0.4357	0.6299	0.6993	0.6151	0.6586	0.4542	0.2969	0.1924	0.0509	0.0231	0.0148	0.0037	0.0018	5.3501
0.03	0.04					0.0028	0.0583	0.7233	0.5272	0.2118	0.3663	0.3950	0.3200	0.2756	0.2183	0.1304	0.0555	0.0203	0.0102	0.0009		3.3160
0.04	0.05						0.0018	0.4486	0.8834	0.3857	0.1045	0.1841	0.2229	0.1554	0.1572	0.1258	0.0620	0.0250	0.0139			2.7703
0.05	0.06							0.1720	0.7169	0.6225	0.1350	0.0684	0.1165	0.0601	0.0684	0.0601	0.0573	0.0176	0.0157	0.0009		2.1117
0.06	0.07							0.0564	0.4199	0.7261	0.2951	0.0610	0.0462	0.0314	0.0287	0.0296	0.0462	0.0222	0.0139			1.7769
0.07	0.08							0.0166	0.1323	0.4116	0.3330	0.0675	0.0166	0.0176	0.0157	0.0166	0.0157	0.0111	0.0120	0.0018		1.0683
0.08	0.09							0.0018	0.0268	0.2405	0.3959	0.1267	0.0157	0.0074	0.0046	0.0046	0.0046	0.0028	0.0120			0.8436
0.09	0.10								0.0046	0.1119	0.2830	0.1933	0.0166	0.0009	0.0028	0.0028	0.0028	0.0046	0.0037			0.6271
0.10	0.11									0.0361	0.1794	0.1545	0.0166	0.0037	0.0009		0.0009	0.0037	0.0018			0.3977
0.11	0.12								0.0009	0.0102	0.1008	0.1526	0.0305	0.0018	0.0018	0.0009		0.0009	0.0028			0.3034
0.12	0.13									0.0074	0.0472	0.1073	0.0518	0.0092	0.0009			0.0018	0.0009			0.2266
0.13	0.14										0.0157	0.0444	0.0601	0.0111	0.0009	0.0009		0.0018	0.0018			0.1369
0.14	0.15										0.0028	0.0213	0.0657	0.0166	0.0028	0.0009		0.0018	0.0009			0.1128
0.15	0.16										0.0018	0.0250	0.0731	0.0176	0.0037	0.0009		0.0009	0.0009			0.1239
0.16	0.17											0.0120	0.0370	0.0111	0.0055	0.0009						0.0666
0.17	0.18											0.0055	0.0231	0.0102	0.0018	0.0028			0.0009			0.0444
0.18	0.19												0.0129	0.0046	0.0028	0.0018		0.0009	0.0018			0.0250
0.19	0.20											0.0009	0.0009	0.0028	0.0046				0.0009			0.0102
0.20	0.21											0.0009	0.0018	0.0009	0.0046	0.0009	0.0009					0.0102
0.21	0.22														0.0009							0.0009
0.22	0.23												0.0009									0.0009
	Sum	60.9633	0.0000	0.0000	0.0000	2.2653	3.1542	4.3011	5.7348	6.0114	5.3972	4.2077	3.1828	1.9545	1.2829	0.8325	0.3968	0.1804	0.1239	0.0074	0.0037	100.0000

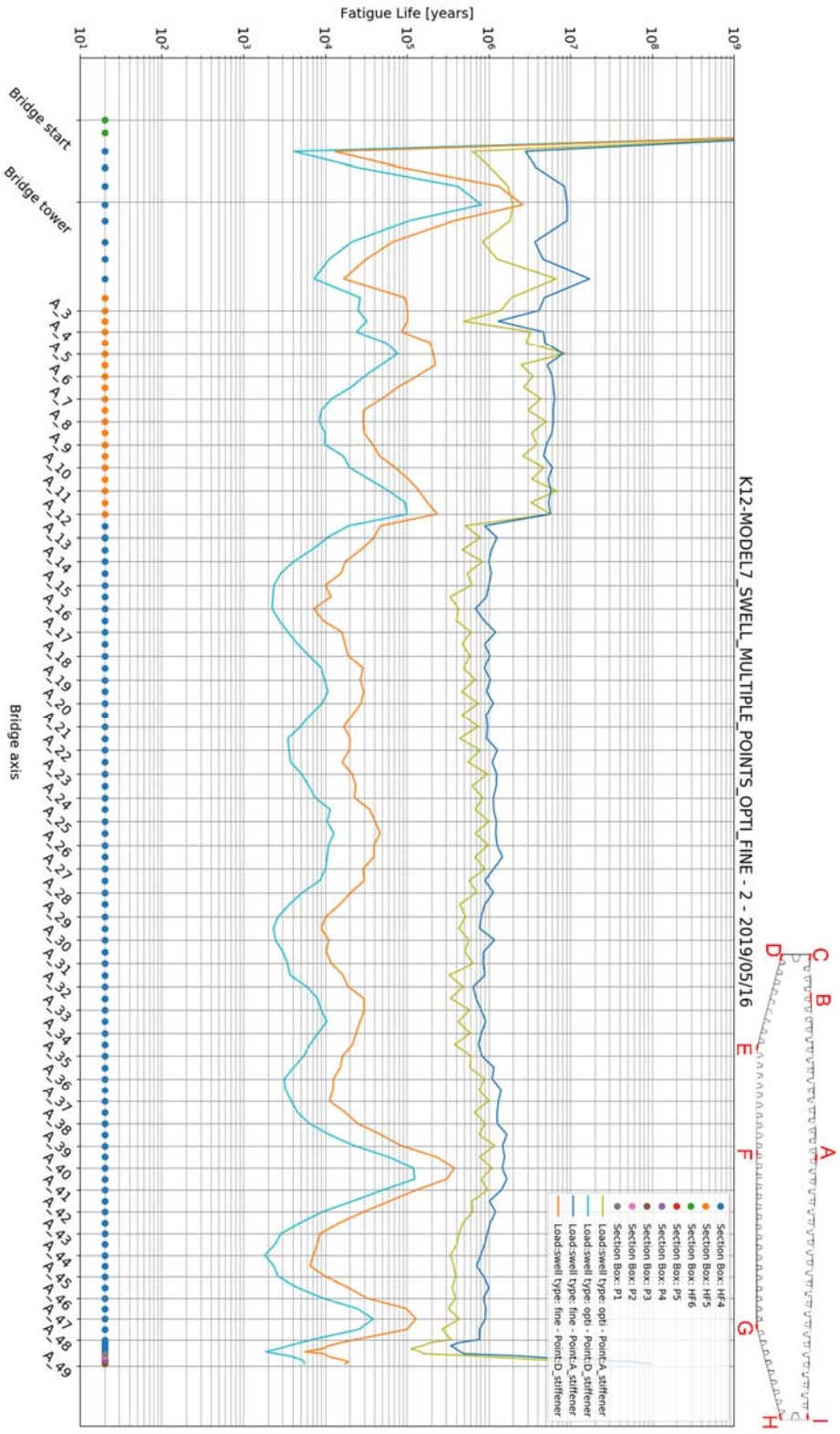
> *Figure 28: Lumping of swell scatter diagram*

Hs\Tp	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5
0.0-0.03	3.84E-09	1.36E-08	1.08E-08	3.64E-08	1.67E-07	4.38E-07	1.30E-06	2.28E-06	1.60E-06	7.81E-07	5.87E-07	2.43E-07	2.57E-07	1.39E-08	1.73E-09	1.01E-09
0.03-0.06	6.40E-09	1.67E-07	6.31E-06	2.27E-05	8.28E-05	9.70E-05	1.65E-04	7.73E-04	7.79E-04	5.42E-04	3.44E-04	5.11E-04	6.01E-05	1.01E-05	1.07E-06	
0.06-0.09			5.05E-06	1.19E-04	1.20E-03	1.88E-03	1.90E-03	1.84E-03	1.82E-03	1.30E-03	1.36E-03	1.29E-03	9.99E-04	3.58E-04	2.33E-05	
0.09-0.12				9.65E-06	1.34E-03	9.80E-03	2.62E-02	1.37E-02	1.24E-03	6.78E-04	9.49E-04	5.28E-04	6.99E-04	4.23E-04		
0.12-0.15					2.73E-04	6.56E-03	6.03E-02	2.22E-01	1.91E-02	4.27E-03	3.31E-03		2.69E-03	1.57E-03		
0.15-0.18						4.80E-04	3.16E-02	2.22E-01	8.31E-02	2.86E-02	8.25E-03			2.24E-03		
0.18-0.21							2.44E-03	8.30E-02	4.82E-02	7.32E-02	1.64E-02			6.89E-03		

> *Figure 29: Swell damage ratio per case basis for optimization*



> *Figure 30: Swell damage ratio per lumped case after optimization*



> *Figure 31: Swell fatigue life for full resolution (fine) and optimized scatter diagram (opti) Chosen fatigue cases and combinations*

3 CHOSEN FATIGUE CASES AND COMBINATIONS

In this section the full case- and combination matrices for the environmental loads are shown.

> *Table 1: Wind sea case matrix*

Case	*Hs*	*Tp*	*Dir*	*p_case*
1	0.25	1.75	0	0.03715
2	0.25	3.25	0	0.000313
3	0.45	2.75	0	0.000179
4	0.55	3.75	0	0.000134
5	0.85	3.75	0	5.21E-05
6	0.85	4.25	0	1.49E-05
7	0.35	1.75	30	0.03174
8	0.35	3.25	30	0.000179
9	0.45	3.25	30	4.47E-05
10	0.25	1.75	60	0.034486
11	0.25	3.25	60	0.000923
12	0.55	3.25	60	0.002136
13	0.65	3.75	60	2.98E-05
14	0.25	1.75	90	0.098099
15	0.25	3.25	90	0.004242
16	0.55	3.75	90	0.006489
17	0.65	2.75	90	0.026836
18	0.85	3.25	90	0.00288
19	0.95	4.25	90	0.002582
20	1.25	4.25	90	0.000625
21	0.25	1.75	120	0.056216
22	0.25	3.25	120	0.001808
23	0.65	2.75	120	0.01277
24	0.65	3.75	120	0.002538
25	1.05	3.75	120	0.001049
26	1.05	4.25	120	0.000156
27	0.25	1.75	150	0.066605
28	0.25	3.25	150	0.001325
29	0.55	2.25	150	0.021857
30	0.65	2.75	150	0.013321
31	0.65	3.25	150	0.001421
32	0.65	3.75	150	8.93E-05
33	0.75	3.25	150	0.001176
34	0.85	3.75	150	5.21E-05
35	0.95	3.25	150	0.000767

36	1.05	3.75	150	0.000127
37	0.25	1.75	180	0.06502
38	0.25	3.25	180	0.003222
39	0.55	2.25	180	0.007092
40	0.55	2.75	180	0.007003
41	0.55	3.25	180	0.002865
42	0.55	3.75	180	0.000134
43	0.75	3.25	180	0.000863
44	0.75	3.75	180	0.000461
45	0.85	2.75	180	0.001503
46	0.95	3.25	180	0.000246
47	0.95	3.75	180	0.000231
48	0.25	1.75	210	0.101084
49	0.25	3.25	210	0.003944
50	0.45	2.75	210	0.034828
51	0.45	3.75	210	0.001831
52	0.55	3.25	210	0.003766
53	0.65	2.75	210	0.003944
54	0.65	3.25	210	0.004168
55	0.65	3.75	210	0.000335
56	0.75	3.25	210	0.001488
57	0.75	3.75	210	0.000901
58	0.85	3.25	210	0.000171
59	0.85	3.75	210	0.001139
60	0.95	3.25	210	7.4E-06
61	0.95	3.75	210	0.000342
62	1.05	3.75	210	4.47E-05
63	1.05	4.25	210	0.000127
64	1.15	3.75	210	7.4E-06
65	1.15	4.25	210	1.49E-05
66	1.35	4.25	210	1.49E-05
67	0.45	1.75	240	0.044131
68	0.45	3.25	240	0.002486
69	0.75	3.25	240	0.003803
70	1.05	3.25	240	0.000514
71	0.45	1.75	270	0.045106
72	0.45	3.25	270	0.00358
73	0.75	3.25	270	0.004287
74	0.95	3.75	270	0.001005
75	1.15	3.75	270	0.000283
76	1.35	3.75	270	0.000067
77	0.45	1.75	300	0.08483
78	0.45	3.25	300	0.043639
79	0.75	3.25	300	0.018984

80	0.85	3.75	300	0.007263
81	0.85	4.25	300	0.000476
82	0.95	3.75	300	0.001392
83	0.95	4.25	300	0.000409
84	1.05	3.75	300	0.000327
85	1.05	4.25	300	0.000514
86	1.25	3.75	300	7.44E-05
87	1.25	4.25	300	0.000461
88	1.45	4.25	300	0.000141
89	1.45	4.75	300	8.19E-05
90	1.75	4.75	300	0.000067
91	0.45	1.75	330	0.043208
92	0.45	3.25	330	0.013395
93	0.65	3.75	330	0.0007
94	0.75	3.25	330	0.001258
95	0.85	3.75	330	0.000208
96	0.85	4.25	330	7.44E-05

> *Table 2: Wind case matrix*

Case	*U*	*Dir*	*p_case*
1	3.63	0	0.037463
2	5.77	0	0.000179
3	6.51	0	0.000134
4	9.9	0	0.000067
5	4.11	30	0.031918
6	7.36	30	4.47E-05
7	3.44	60	0.035409
8	6.11	60	0.002136
9	8.26	60	2.98E-05
10	3.88	90	0.102341
11	6.52	90	0.006489
12	7.02	90	0.026836
13	8.73	90	0.00288
14	9.49	90	0.002582
15	12.01	90	0.000625
16	4.05	120	0.058025
17	8.01	120	0.015308
18	11.33	120	0.001206
19	4.23	150	0.06793
20	7.82	150	0.021857
21	8.61	150	0.014832
22	11.35	150	0.001176

23	11.47	150	5.21E-05
24	12.15	150	0.000767
25	13.43	150	0.000127
26	3.92	180	0.068242
27	7.29	180	0.017094
28	10.06	180	0.001325
29	10.74	180	0.001503
30	11.83	180	0.000476
31	3.94	210	0.105028
32	6.54	210	0.036659
33	8.35	210	0.003766
34	9.77	210	0.008447
35	10.75	210	0.002389
36	11.94	210	0.00131
37	12.72	210	0.00035
38	13.69	210	0.000171
39	16.66	210	2.23E-05
40	14.33	210	1.49E-05
41	5.93	240	0.046616
42	10.32	240	0.003803
43	13.05	240	0.000514
44	5.53	270	0.048685
45	9.4	270	0.004287
46	11.9	270	0.001005
47	13.8	270	0.000283
48	14.72	270	0.000067
49	5.08	300	0.12847
50	8.28	300	0.018984
51	8.97	300	0.00774
52	10.87	300	0.001801
53	11.84	300	0.000841
54	12.83	300	0.000536
55	15.11	300	0.000223
56	16.62	300	0.000067
57	4.91	330	0.056603
58	7.54	330	0.0007
59	7.8	330	0.001258
60	8.81	330	0.000283

> *Table 3: Swell case matrix*

Case	*Hs*	*Tp*	*Dir*	*p_case*
1	0.025	20.5	300	0.000037
2	0.035	5.5	300	0.02265

3	0.035	12.5	300	0.02373
4	0.045	6.5	300	0.03154
5	0.045	9.5	300	0.03845
6	0.065	8.5	300	0.0557
7	0.065	10.5	300	0.04038
8	0.065	11.5	300	0.03296
9	0.065	12.5	300	0.003857
10	0.065	13.5	300	0.01839
11	0.065	14.5	300	0.01228
12	0.065	15.5	300	0.007983
13	0.065	16.5	300	0.003718
14	0.065	17.5	300	0.001498
15	0.065	18.5	300	0.000833
16	0.075	19.5	300	0.000074
17	0.085	7.5	300	0.04301
18	0.085	9.5	300	0.02001
19	0.095	11.5	300	0.003876
20	0.095	12.5	300	0.00049
21	0.095	16.5	300	0.000241
22	0.105	10.5	300	0.01191
23	0.105	17.5	300	0.000222
24	0.105	18.5	300	0.000296
25	0.115	8.5	300	0.001646
26	0.115	11.5	300	0.003071
27	0.115	12.5	300	0.000472
28	0.115	13.5	300	0.000315
29	0.125	9.5	300	0.001656
30	0.125	12.5	300	0.000518
31	0.125	14.5	300	0.000268
32	0.125	15.5	300	0.00025
33	0.135	11.5	300	0.001517
34	0.135	12.5	300	0.000601
35	0.135	13.5	300	0.000204
36	0.145	10.5	300	0.001683
37	0.145	12.5	300	0.000657
38	0.145	17.5	300	8.33E-05
39	0.155	11.5	300	0.000463
40	0.155	12.5	300	0.000731
41	0.155	13.5	300	0.000342
42	0.155	14.5	300	0.000074
43	0.155	15.5	300	2.78E-05
44	0.155	18.5	300	0.000111
45	0.165	12.5	300	0.00037
46	0.175	11.5	300	0.000176

47	0.175	12.5	300	0.000231
48	0.175	13.5	300	0.000213
49	0.175	14.5	300	0.000074
50	0.175	15.5	300	0.000037
51	0.185	12.5	300	0.00013
52	0.195	13.5	300	8.33E-05
53	0.195	14.5	300	0.000074
54	0.195	15.5	300	2.78E-05
55	0.205	11.5	300	1.85E-05
56	0.205	12.5	300	0.000037
57	0.215	14.5	300	5.55E-05

> *Table 4: Combination matrix*

Case	*WindseaNo*	*WindNo*	*SwellNo*	*p_combi*
1	1	1	29	0.00165600
2	1	1	0	0.03549400
3	2	1	55	0.00001850
4	2	1	0	0.00029410
5	3	2	38	0.00008325
6	3	2	0	0.00009535
7	4	3	49	0.00007400
8	4	3	0	0.00006000
9	5	4	54	0.00002775
10	5	4	0	0.00002435
11	6	4	43	0.00001388
12	6	4	0	0.00000102
13	7	5	39	0.00046250
14	7	5	0	0.03127730
15	8	5	50	0.00003700
16	8	5	0	0.00014160
17	9	6	56	0.00003700
18	9	6	0	0.00000770
19	10	7	51	0.00012950
20	10	7	0	0.03435630
21	11	7	32	0.00024970
22	11	7	0	0.00067310
23	12	8	46	0.00017570
24	12	8	0	0.00196010
25	13	9	43	0.00001388
26	13	9	0	0.00001593
27	14	10	8	0.03296000

28	14	10	0	0.06513930
29	15	10	1	0.00003700
30	15	10	0	0.00420490
31	16	11	27	0.00047170
32	16	11	0	0.00601770
33	17	12	11	0.01228000
34	17	12	0	0.01455550
35	18	13	48	0.00021270
36	18	13	0	0.00266730
37	19	14	41	0.00034220
38	19	14	0	0.00224010
39	20	15	47	0.00023120
40	20	15	0	0.00039390
41	21	16	35	0.00020350
42	21	16	0	0.05601270
43	22	16	53	0.00007400
44	22	16	0	0.00173440
45	23	17	25	0.00164600
46	23	17	0	0.01112430
47	24	17	15	0.00083250
48	24	17	0	0.00170520
49	25	18	40	0.00073070
50	25	18	0	0.00031860
51	26	18	57	0.00005550
52	26	18	0	0.00010080
53	27	19	18	0.02001000
54	27	19	0	0.04659510
55	28	19	28	0.00031450
56	28	19	0	0.00101020
57	29	20	31	0.00026820
58	29	20	0	0.02158870
59	30	21	13	0.00371800
60	30	21	0	0.00960300
61	31	21	21	0.00024050
62	31	21	0	0.00118090
63	32	21	42	0.00007400
64	32	21	0	0.00001530
65	33	22	44	0.00011100
66	33	22	0	0.00106480
67	34	23	52	0.00004163
68	34	23	0	0.00001047
69	35	24	34	0.00060120
70	35	24	0	0.00016530

71	36	25	16	0.00007400
72	36	25	0	0.00005250
73	37	26	3	0.02373000
74	37	26	0	0.04129000
75	38	26	45	0.00037000
76	38	26	0	0.00285230
77	39	27	9	0.00385700
78	39	27	0	0.00323510
79	40	27	33	0.00151700
80	40	27	0	0.00548580
81	41	27	20	0.00049020
82	41	27	0	0.00237490
83	42	27	52	0.00004163
84	42	27	0	0.00009238
85	43	28	23	0.00022200
86	43	28	0	0.00064130
87	44	28	24	0.00029600
88	44	28	0	0.00016540
89	45	29	37	0.00065670
90	45	29	0	0.00084660
91	46	30	30	0.00017267
92	46	30	0	0.00007293
93	47	30	30	0.00017267
94	47	30	0	0.00005803
95	48	31	22	0.01191000
96	48	31	0	0.08917350
97	49	31	30	0.00017267
98	49	31	0	0.00377153
99	50	32	4	0.03154000
100	50	32	0	0.00328820
101	51	32	14	0.00149800
102	51	32	0	0.00033270
103	52	33	26	0.00307100
104	52	33	0	0.00069460
105	53	34	19	0.00387600
106	53	34	0	0.00006820
107	54	34	36	0.00168300
108	54	34	0	0.00248450
109	67	41	5	0.03845000
110	67	41	0	0.00568060
111	68	41	12	0.00199575
112	68	41	0	0.00048985
113	69	42	12	0.00299363

114	69	42	0	0.00080917
115	71	44	2	0.02265000
116	71	44	0	0.02245550
117	72	44	12	0.00299363
118	72	44	0	0.00058597
119	73	45	10	0.00367800
120	73	45	0	0.00060850
121	77	49	6	0.05570000
122	77	49	0	0.02913040
123	78	49	17	0.04301000
124	78	49	0	0.00062940
125	79	50	10	0.01471200
126	79	50	0	0.00427230
127	91	57	7	0.04038000
128	91	57	0	0.00282780
129	55	34	0	0.00033490
130	56	35	0	0.00148840
131	57	35	0	0.00090050
132	58	36	0	0.00017120
133	59	36	0	0.00113860
134	60	37	0	0.00000740
135	61	37	0	0.00034230
136	62	38	0	0.00004470
137	63	38	0	0.00012650
138	64	39	0	0.00000740
139	65	39	0	0.00001490
140	66	40	0	0.00001490
141	70	43	0	0.00051350
142	74	46	0	0.00100470
143	75	47	0	0.00028280
144	76	48	0	0.00006700
145	80	51	0	0.00726330
146	81	51	0	0.00047630
147	82	52	0	0.00139160
148	83	52	0	0.00040930
149	84	53	0	0.00032740
150	85	53	0	0.00051350
151	86	54	0	0.00007440
152	87	54	0	0.00046140
153	88	55	0	0.00014140
154	89	55	0	0.00008190
155	90	56	0	0.00006700
156	92	57	0	0.01339540

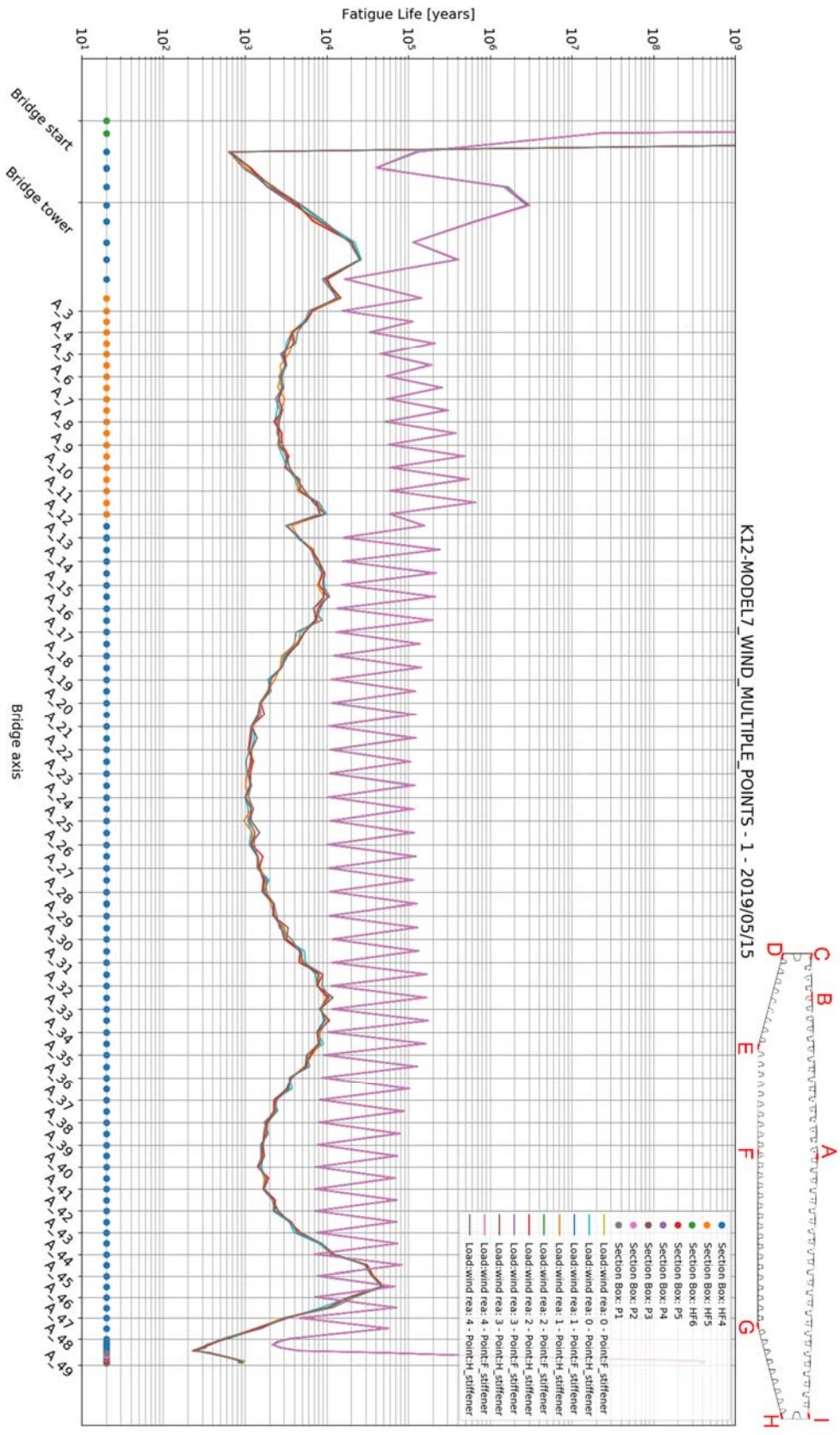
157	93	58	0	0.00069950
158	94	59	0	0.00125770
159	95	60	0	0.00020840

4 TIME SERIES REALIZATION SENSITVITY

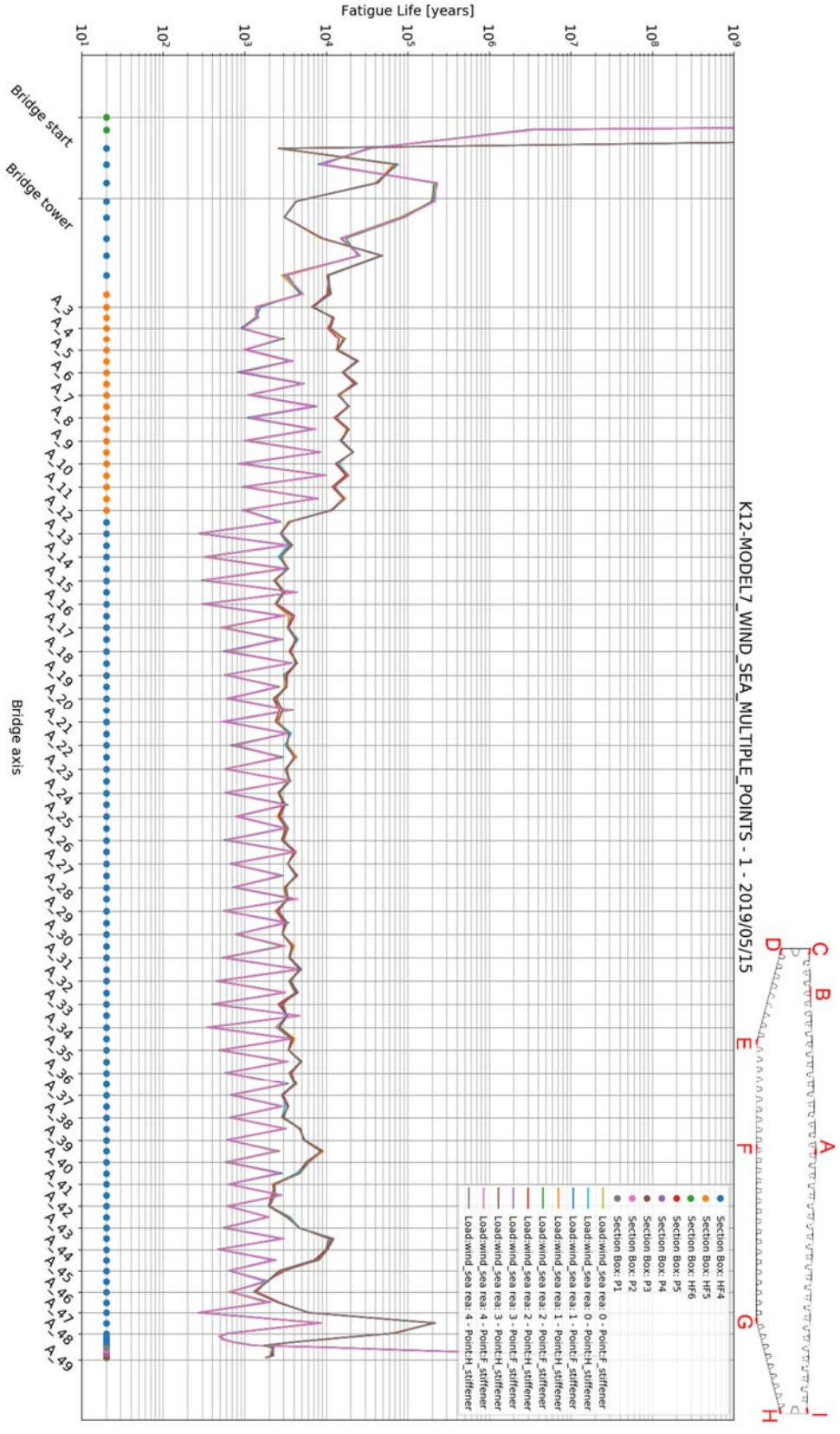
The fatigue damage is calculated using the rainflow count method on generated stress time series realizations. To verify that the fatigue life is not realization sensitive, 5 realizations from a single analysis is generated and the fatigue life calculated for wind, wind sea and swell are compared.

In these investigations a constant lumping of the wave scatter diagrams is used. For wind sea the resolution on the Hs-axis was 0.2 m and 1 s on the Tp-axis. For swell the resolution was 0,05 m and 1 s in the Hs- and Tp-axis respectively, and the mean value of both Tp and Hs in each block was used. The discretization of mean wind velocity was given according to the resolution of the wind sea Hs- axis.

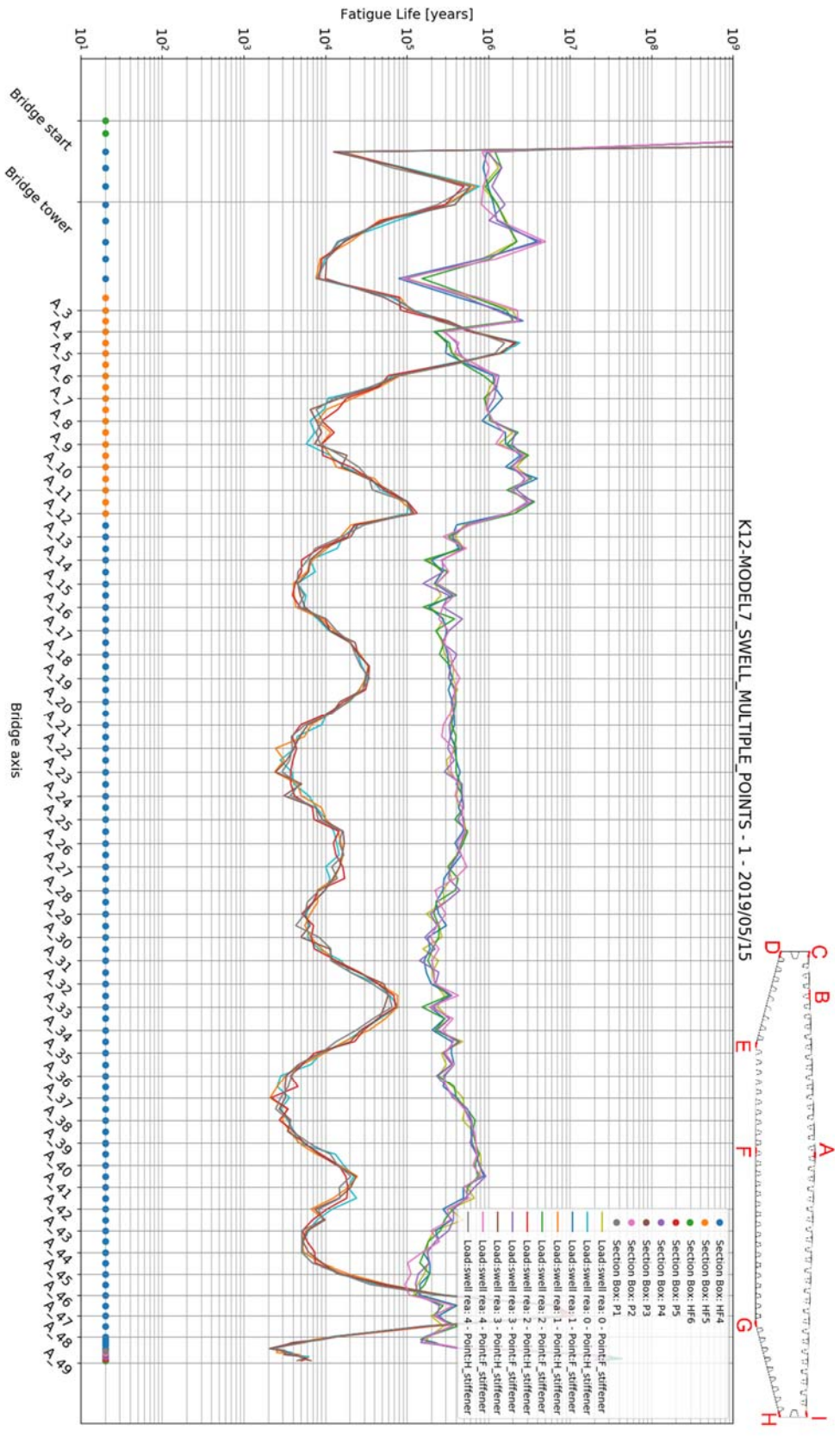
The following figures show the calculated fatigue life for 5 different time series realizations for wind, wind sea and swell respectively. The results clearly show little effect on the fatigue life estimation, indicating that a single realization is enough to estimate the fatigue life from environmental loads for this structure.



> *Figure 32: Wind load fatigue life for 5 different realizations*



> *Figure 33: Wind sea fatigue life for 5 different realizations*



> *Figure 34: Swell fatigue life for 5 different realizations*

5 REFERENCES

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