Contents

1 Introduction **3**

1.1 General introduction . . . 3
1.1.1 Relevance of the topic . . . 3
1.2 Background . . . 4
1.3 Initial Hypothesis . . . 6
1.3.1 Boreal wetlands . . . 6
1.3.2 Tropical wetlands . . . 7
1.3.3 Clathrates . . . 7
1.3.4 Geological sources . . . 8
1.4 Current state of research . . . 8
1.4.1 Paleo-enviroments . . . 8
1.4.2 Modelling CH_4 . . . 9
1.5 Aims and objectives . . . 10
1.6 Thesis approach and outline . . . 11

2 Uncertainties: effect of hydrological model and structure **15**

2.1 Abstract . . . 15
2.2 Introduction . . . 16
2.3 Models . . . 17
2.3.1 Previous modelling experiments . . . 17
2.3.2 Modelling experiments in this study . . . 18
2.4 Modelled climate changes . . . 20
2.4.1 Paleogeography: climate and environment . . . 20
2.4.2 Paleogeography: wetland distribution . . . 22
2.4.3 Present climate and environment and model validation . . . 22
2.5 Results . . . 25
2.5.1 Comparison of modelled values with data for MODERN climate . 25
2.5.2 Sensitivity to CH_4 production parameters in PEATLAND . . . 25
2.5.3 Sensitivity to hydrology and CH_4 emission model structure . . . 28
2.6 Discussion . . . 30
2.6.1 Model structure . . . 30
2.7 Conclusions . . . 33

3 Uncertainties modelling CH_4 emissions from northern wetlands in glacial climates: the role of vegetation parameters 35
3.1 Abstract . . . 35
3.2 Introduction . . . 36
3.3 Effects of plants on CH_4 fluxes . . . 39
3.4 Modelling experiments . . . 41
3.4.1 The PEATLAND-VU model . . . 41
3.4.2 Climate model input to PEATLAND-VU . . . 41
3.4.3 Model runs . . . 42
3.5 Results . . . 43
3.6 Discussion . . . 46
3.7 Conclusions . . . 49

4 Methane emission from permafrost thaw lakes limited by lake drainage 55
4.1 Abstract . . . 55
4.2 Introduction . . . 56
4.3 The model . . . 56
4.3.1 Approach . . . 56
4.3.2 Drivers and settings . . . 56
4.4 Test and validation . . . 57
4.4.1 The TERRAIN experiment . . . 57
4.4.2 The ICEGROWTH experiment . . . 57
4.4.3 The TIMING experiment . . . 57
4.4.4 The FUTURE experiment . . . 58
4.5 Methods . . . 58
4.6 Results and discussion . . . 60

5 Permafrost ecosystem: wetlands characteristics and their influence on CH_4 emissions in a drained thaw lake basin, northeastern Siberia 67
5.1 Abstract . . . 67
5.2 Introduction . . . 68
5.3 General settings of the site . . . 70
5.4 Analytical techniques and methods . . . 73
5.4.1 Soil analyses . . . 73
5.4.2 CH_4 oxidation rate analysis . . . 74
5.4.3 DNA analysis . . . 76
5.4.4 CH_4 flux measurements . . . 76
5.5 Results . . . 77
5.5.1 Soils . . . 77
5.5.2 CH_4 oxidation rates . . . 83
5.5.3 DNA . . . 85
5.5.4 CH_4 flux measurements . . . 86
5.6 Discussion . . . 87
5.7 Conclusions . . . 90

6 Paleo-thaw lakes and their role as CH_4 sources **93**
6.1 Abstract . . . 93
6.2 Introduction . . . 93
6.3 Study area . . . 96
6.4 Methods . . . 98
6.4.1 Cores and section logs . . . 98
6.4.2 Grain size distribution analysis . . . 99
6.4.3 Organic Carbon analysis . . . 99
6.4.4 DNA analysis . . . 99
6.4.5 Radiocarbon dating . . . 99
6.5 Results . . . 100
6.5.1 Cores and section logs . . . 100
6.5.2 Grain size distribution analysis . . . 104
6.5.3 Organic Carbon analysis . . . 104
6.5.4 DNA analysis . . . 108
6.5.5 Radiocarbon dating . . . 109
6.5.6 Stratigraphy . . . 109
6.5.7 Sedimentation rates . . . 110
6.5.8 Weichselian environmental change recorded in the Hengelo area . 110
6.5.9 Weichselian environmental change recorded in the Ootmarsum area 112
6.5.10 Weichselian environmental change recorded in the Orvelte exposure 113
6.6 Discussion . . . 113
6.7 Conclusions . . . 115

7 Conclusions **117**
7.1 The initial questions . . . 117
7.2 Main findings of this thesis . . . 118
7.3 Current state of modelling northern wetland CH_4 fluxes . . . 119
7.4 Summary . . . 119
7.4.1 Chapter 2 . . . 120
7.4.2 Chapter 3 . . . 121
7.4.3 Chapter 4 . . . 122
7.4.4 Chapter 5 . . . 123
7.4.5 Chapter 6 . . . 124
7.5 A critical look . . . 125
7.6 Going forward . . . 127

8 Nederlandse samenvatting **129**
8.1 De onderzoeksvragen en hypothesen . . . 129
8.2 Belangrijkste resultaten van dit onderzoek . . . 130
8.3 Huidige status van modellering methaanfluxen . . . 131
8.4 Samenvatting . . . 132
8.4.1 Hoofdstuk 2 . . . 132
8.4.2 Hoofdstuk 3 . . . 134
8.4.3 Hoofdstuk 4 . . . 135
8.4.4 Hoofdstuk 5 . . . 136
8.4.5 Hoofdstuk 6 . . . 137

8.5 Een kritische blik 138
8.6 Een vooruitblik 139

Appendix **173**