Reply to comments by reviewer 1 on "Palaeo-modeling of coastal salt water intrusion during the Holocene: an application to the Netherlands" by J. R. Delsman et al.

We thank reviewer 1 for his/her kind words and helpful suggestions. Questions raised by the reviewer are in bold face, our answers in regular face.
On behalf of all coauthors,

Joost Delsman

General comment

This paper discusses a very interesting topic of complicated salinity distribution in coastal aquifer and provides a unique approach of hydrological modelling combined with hydrochemical considerations. I, therefore, strongly recommend that it will be published in this journal provided some significant modifications will be made. The main problem is that the paper is quite difficult to follow and some parts can't be judged by the readers due to lack of explanations. Some of these modifications are relatively easy to make, such as showing some of the figure in colors so that it will easier for the readers to notice the specific details. Other will require more work, such providing more information about the different geochemical data so that the readers will not need to go to another previous paper in order to understand the current one. I am sure that some of specific comments stems from my lack of understanding that can be dealt with by farther explanations.

We thank reviewer 1 again for his/her kind words and helpful suggestions and will do our best to improve our paper accordingly.

Specific comments

Abstract

1) The abstract is well written but a little too general. It will be nice to have more specific results of this study in the abstract, possibly relating to the use of the geochemical groups.

We pretty much completely revised the abstract and included more specific results.

2) The first several lines are kind of introduction and can be shortened.

We shortened the first four lines of the abstract.

3) I am not sure that the term "perceptual tool" is the correct one here – why not "conceptual tool"?

We changed perceptual to conceptual throughout the paper.

4) Where is the information for "pre-Holocene" coming from? Is it from radiocarbon dating of this water? If yes, then you need to change the text where it is written that radiocarbon is not

accurate and can't be used. If this time frame is obtained from the simulations, it should be specified as such.

The original statement was based on our modeling results, where water initially present in the model domain (termed pre-Holocene for easier recognition) required a minimum chloride concentration to match its current location. We changed the text in the abstract to emphasize that this statement is based on our modeling results.

On a side note: our understanding of this "current location" is indeed partly based on radiocarbon dating, but allowable given the large age contrasts considered (Post, 2004). Our statement on the accuracy of radiocarbon dating in the Methods sections was directed at groundwater dating with a much higher resolution; see also our answer to the reviewer's specific question relating to the accuracy of the radiocarbon measurements.

5) The last sentence is too general – I suggest that you elaborate and be more specific or delete

We included the gist of the concluding sentence in the reworking of the abstract and deleted the last sentence.

<u>Introduction</u>

This chapter is well written but I missed some needed information with regards to the details of this studied area.

First, I suggest to have a chapter of "site description" as a second part of the introduction and move what you write in the "method" chapter to this chapter.

We moved the description of the study area and its palaeogeographic development from the methods chapter to a separate 'site description' chapter, immediately following the Introduction.

Second, you need to give a better summary about the concept of "hydrosome" and hydrochemical facies and characteristics of each of them from the published papers of Stuyfzand. The description in the "Hydrochemical facies analysis (HYFA)" chapter is not elaborated enough. The lack of such information make this paper difficult to read – the readers should be able to understand the paper as is and not to be forced to read the previous papers.

We moved the description of HYFA to the site description chapter, and elaborated the section to make it more self-explanatory, by briefly describing the 6 hydrosomes in the area and the 4 hydrochemical facies parameters, which in combination define the hydrochemical zones within a hydrosome.

<u>Methods</u>

It will be better to give more specific details with regards to the recharge coefficients and not just to mention "precipitation surplus (precipitation minus evaporation)". I suggest to give the actual estimations of precipitation and evaporation here and not only the surplus. Is the recharge the same in the whole studied area? Is there no different between the dune area and the other areas some of which seems of lower permeability? Is there no surface flow, which could affect the precipitation surplus?

We split net precipitation in the manuscript in total precipitation (840 mm/y) and evapotranspiration (590 mm/y). We applied uniform recharge over the entire model area, given the lack of data on historical vegetation patterns. Recharge differences related to palaeo-vegetation differences occurring in the Netherlands are in the order of 10% (Van Loon et al., 2009), well within other uncertainties in the model. Overland flow by infiltration excess is very rare in the Netherlands given the low relief and permeable soils and therefore neglected. We did, however, apply infinite drainage at the model surface, to simulate small-scale drainage structures and saturation-excess overland flow. We better clarified this in the text.

Are the Tertiary clay layers the same as Maassluis Formation?

The Maassluis Formation is a formation deposited in the early Pleistocene and situated just above the Tertiairy clay layers. We changed Fig.1b and the text on the model boundary conditions to clarify this.

Is there separation between the different sub-aquifers? Are all parts connected to the sea in the same manner? The system seems to behave as one with only local effects of the less permeable layers. Is this something specific to the studied site or this is a good representation of the Dutch coastal aquifer?

It is indeed typical of the Dutch coastal groundwater system that aquitards are discontinuous, and the system functions, on a large scale, essentially as one (Van der Meulen et al., 2013). In our paper we also show however, that the discontinuous aquitards do still have a pronounced effect on the groundwater salinity distribution.

It is not clear how you used the model of Goode for the age distribution. Moreover, there is no output of such simulation to show the readers what you mean in this part of your work and how do the simulated ages fit the tritium data. As you know, the tritium data give information only for ~50 years which is very small part of this study.

We extended the explanation on the use of Goode's method of age modeling in our paper. We added that we implemented the method of (Goode, 1996) by using MT3DMS in a post-processing step after SEAWAT (saving the flow results), using a zero-th order decay term (of – 1/365, to obtain age in years) in MT3DMS (Zheng, 2009).

Tritium data can only really be used to discern pre-1950s water from younger water, which is indeed only a small part of our study. This information however permits the delineation of infiltrating and exfiltrating parts of the model transect. Earlier versions of this manuscript included a figure of the comparison between the calculated 1952 contour and the limited available tritium samples (Figure R1 in this reply). Unfortunately, the comparison was hampered by the orthogonal projection of samples from several kilometers away (more so than the more abundant head and chloride measurements, used in the paper). The delineation of infiltrating and exfiltrating areas is very localized in this part of the Netherlands, resulting mainly from (anthropogenic) differences in surface level and geology (compaction) and variation in surface water / drainage levels, not only along the model transect, but also perpendicular to it. This variation is obviously not included in the employed 2D modeling approach. As an example, tritium ages show very young water below the Horstermeer (the small reclaimed lake at x-coordinate 135 km attracting saline groundwater). These samples are however taken just north of and outside the Horstermeer, and are more representative of the recharge areas along both sides of the Horstermeer. A similar explanation explains the mismatch around km 122. Given these explanations, we felt that the calculated 1952 age contour (and hence the modeled infiltration / exfiltration patterns) lined up very well with the available data. After some consideration, we excluded output from the age calculations for sake of brevity, the age calculation is however shown in upper right hand panel of the movie included as supplementary information. We feel however that the general good correspondence is worth mentioning and like to keep it in the manuscript. We will change the manuscript to refer readers to the supplementary information for the modeled age results, and better highlight the model simplification resulting from the 2D approach in the discussion.

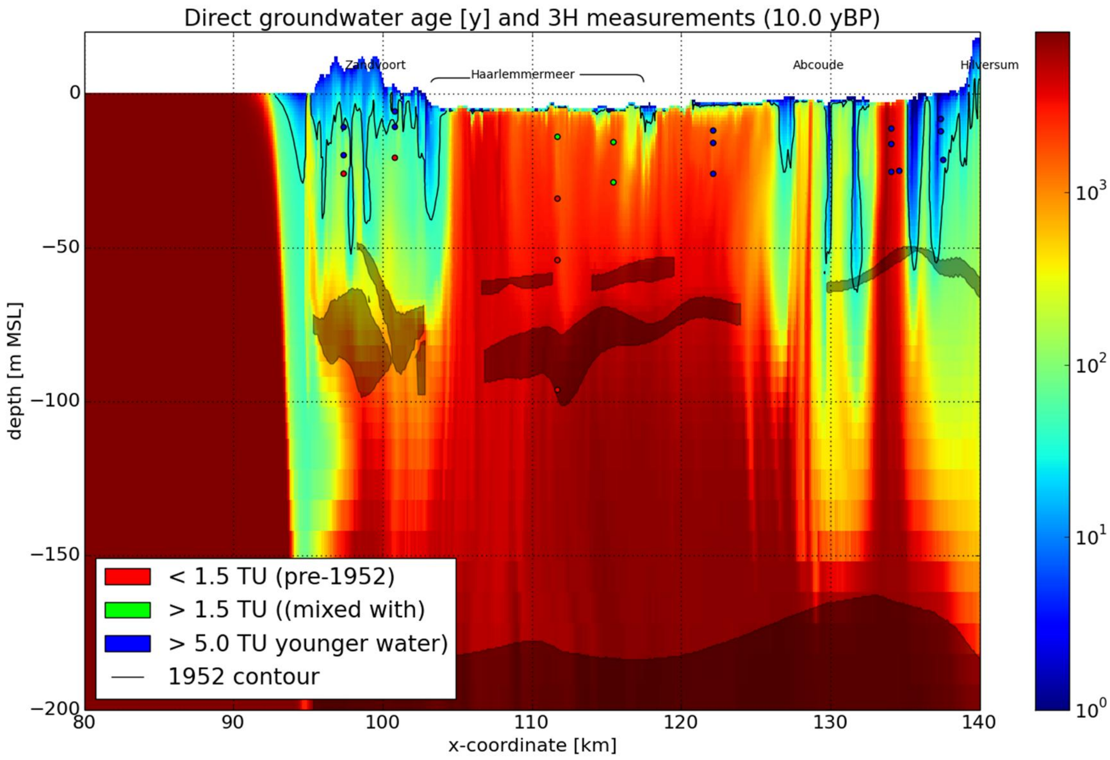

Figure R1: Modeled direct groundwater age (Goode, 1996) at 1990 AD compared to decay-corrected ^{3}H measurements. ^{3}H samples with concentrations less than 1.5 TU are considered older than 1952 AD, higher concentrations are younger or are mixed with younger water. The modeled 1952 contour is shown in black.

Are the radiocarbon ages of Post not accurate or not good at all? If the problem is with accuracy, then you can still use them for this work since, as you state, is more conceptual than quantative.

On the applicability of radiocarbon ages Post (2004) says, in his own words:

"Due to the large contribution of sedimentary carbon sources to groundwater DIC and the heterogeneous age distribution of carbon-bearing materials in the subsurface, accurate radiocarbon dating of the brackish and saline groundwater proved impossible. Carbon-14, however, could be used to distinguish a Holocene from a Pliocene to Early-Pleistocene seawater contribution." (Post, 2004, p. 45)

We opted not to use this data as we are mostly interested in the within-Holocene age variation, and Post (2004) only presents one sample with dates with depths.

Results

As written before, it is impossible for the readers to judge the comparison between the tritium ages and the results of the simulation. If this is important to be mentioned, then you need to give specific results (either as another figure or some specific data)

See response under methods

The explanation for the discrepancy between the results of the simulation and the measured heads at about elevation zero need to be better explained.

We are not sure what discrepancy the reviewer is referring to here, as the fit between modeled and measured heads at elevation zero even seems better than at other elevations. At least, for the measurements excluding the coastal dune area. Discrepancies in the coastal dune area are explained by the fact that measured heads in that area are much influenced by stresses not well included in our model (well fields, artificial recharge). Nevertheless, we changed the manuscript to better clarify discrepancies in the coastal dunes area.

The term "model conservative tracers" is not clear in this work. It seems that in this work it means specific geochemical group, that you define as "hydrosomes". But these need to be better defined. It is not clear how you dealt with them in the simulations. Are there a specific parameter that defines each group, either in the model or in the field or in both ? Is there mixing between the different groups? You also need to define better the other related terms such as "infiltrating transgression" and classic seawater intrusion – is it mostly about the time of the intrusion or there are other differences between these terms? Again, an elaboration in the second part of the "introduction" will be very helpful.

The two terms ('modeled conservative tracer' and 'hydrosome') are two related, but different concepts. The term hydrosome specifically refers to the work of (Stuyfzand, 1993), in which he delineated different groundwater origins based on environmental tracers. With modeled conservative tracers we refer to our approach to model the evolution of specific origins of groundwater through modeling fictitious tracers that represent the fraction of groundwater with a specific origin (e.g., the origin 'surface water' is modeled by applying a concentration of 1 of the tracer 'surface water' at river boundary conditions). These two are obviously related, which allows us to compare the model result with the hydrosome delineation of (Stuyfzand, 1993). The modeled origin tracers do however not map one to one to the hydrosomes. Next to elaborating the description of hydrosomes and the HYFA analysis as previously mentioned, we will better explain the modeling approach in our manuscript, change the term 'conservative tracer' to 'origin tracer' and expand Table 1 (description of origin tracers) with their relation with hydrosomes. Specific references to origin tracers have been formalized by referring to their names in Table 1 (instead of vaguer process-descriptions like infiltrating transgression water) with capitalized first letters.

Discussion

The differences in the thickness of the mixing zones in the different parts of the section are interesting. Can you be more specific and mention what you mean by wide or narrow zone? Also, can you elaborate on the reasons for this difference? Could the flow velocity (of the fresh water) be an important factor?

We specified the widths in the discussion (narrow: some meters, wide: several tens of meters) and added several lines in the Discussion to elaborate on the reasons for this difference.

We argue that there exists a distinct difference between the process driving mixing underneath the coastal dunes and that more inland. Beneath the coastal dunes exists a more or less stable BGH lens, where a shallow mixing zone results from transversal dispersivity and diffusion where the fresh and saline waters meet. More inland however, large scale mixing occurred during transgression, where transgrading seawater rapidly infiltrated by means of unstable fingering (Kooi et al., 2000; Post and Kooi, 2003). Kooi et al. (2000) describe the mixing process, and the resulting fairly stable zone of intermediate salinity, by two occurring phases: (1) the development of small-scale fingers (fingers with widths in the order of meters), protruding quickly all the way to the aquifer bottom with limited dispersion, and (2) negligible flow after the fingers reached the bottom, after which diffusion dominates the exchange between the saline fingers and the intermediate fresh water. Our larger model cell size prohibited, however, the modeling of the small-scale fingering and the accompanying mixing observed by these authors. A larger dispersivity value (α_L = 1m) was needed to mimic the mixing result of these small-scale processes in our (necessarily) coarser model cells. This larger value in turn resulted in an apparent overestimation of the mixing zone underneath the coastal dunes. A dual porosity approach (Lu et al., 2009) could perhaps yield better results, but was outside the scope of the present paper.

I am not sure that this approach is so different from the others that start with steady state condition. It seems to me that the conditions that you use for 6500 BC could be defined as steady state condition and the results will not be very different. The interesting point in this work is that you also change the hydrogeological configuration with time.

The main point that we wished to convey regarding steady-state, is that in order to create a transport model of a similar groundwater system for current conditions or future predictions, one shouldn't start with a steady-state that is conditioned on present-day boundary conditions. We will make this clearer in the manuscript. But even in our case, starting with a steady state would explicitly entail neglecting the salinity in the Maassluis formation (groundwater system would be completely fresh except for saltwater intrusion along the coastline), while we showed that the salinity of the Maassluis formation is important in correctly modeling the salinity evolution.

The actual way that this is done and its effect on the modeling is not elaborated enough. I understood that the end condition of each step is the initial condition for the next step – but, did such exercise create problems since these conditions do not fit the new configuration? In real life, the geological and hydrological condition are changed gradually and not in in jumps, some of which are quite big.

The jumps in boundary conditions (time slices) are another aspect of simplification of the complex reality. Like we chose spatial and temporal discretizations etc., we chose ten big steps in geological and hydrological condition. The jumps in geology and/or boundary conditions were indeed sometimes large, but we did not encounter any problems on the time-slice transitions, in convergence or otherwise. We elaborated on the time-slice transition procedure by noting that we filled 'new' cells with the uppermost concentration that existed below the new cell. We added a line to the results section stating that we did not run into any convergence problems at the time slice transitions, and we added a line to the discussion section stating that we simplified gradually changing conditions to discrete jumps.

Figures

Figure 1 – (a) – it is very difficult to see the details without colors – is there a reason for giving this figure in black and white? Can you show the bathymetry? It is difficult to see the ridge in the sea, otherwise (b) Again, it will be much better in colors. It is very difficult to see the details especially in the upper parts What do you mean here by heterogeneous (in the legend)? Which parameters?

We added color to Fig 1, and also show the bathymetry of the North Sea and Lake IJssel. We are not sure what the reviewer means by the 'ridge in the sea', but suspect it to stem from possible confusion between the modeled transect (A-B) and the geological profile (A'-B). We more clearly marked the extent of the geological profile in Fig 1.

'Heterogeneous' in Fig 1 are not further lithologically differentiated formation members of the geological classification used by the Geological Survey of the Netherlands, due to a lack of borehole information. (Uniform) Hydraulic parameters are however assigned to these formations by the Geological Survey (Van der Meulen et al., 2013; Vernes and Van Doorn, 2005; Weerts et al., 2005). We changed the label from 'heterogeneous' to 'undifferentiated' in Fig 1b to avoid confusion.

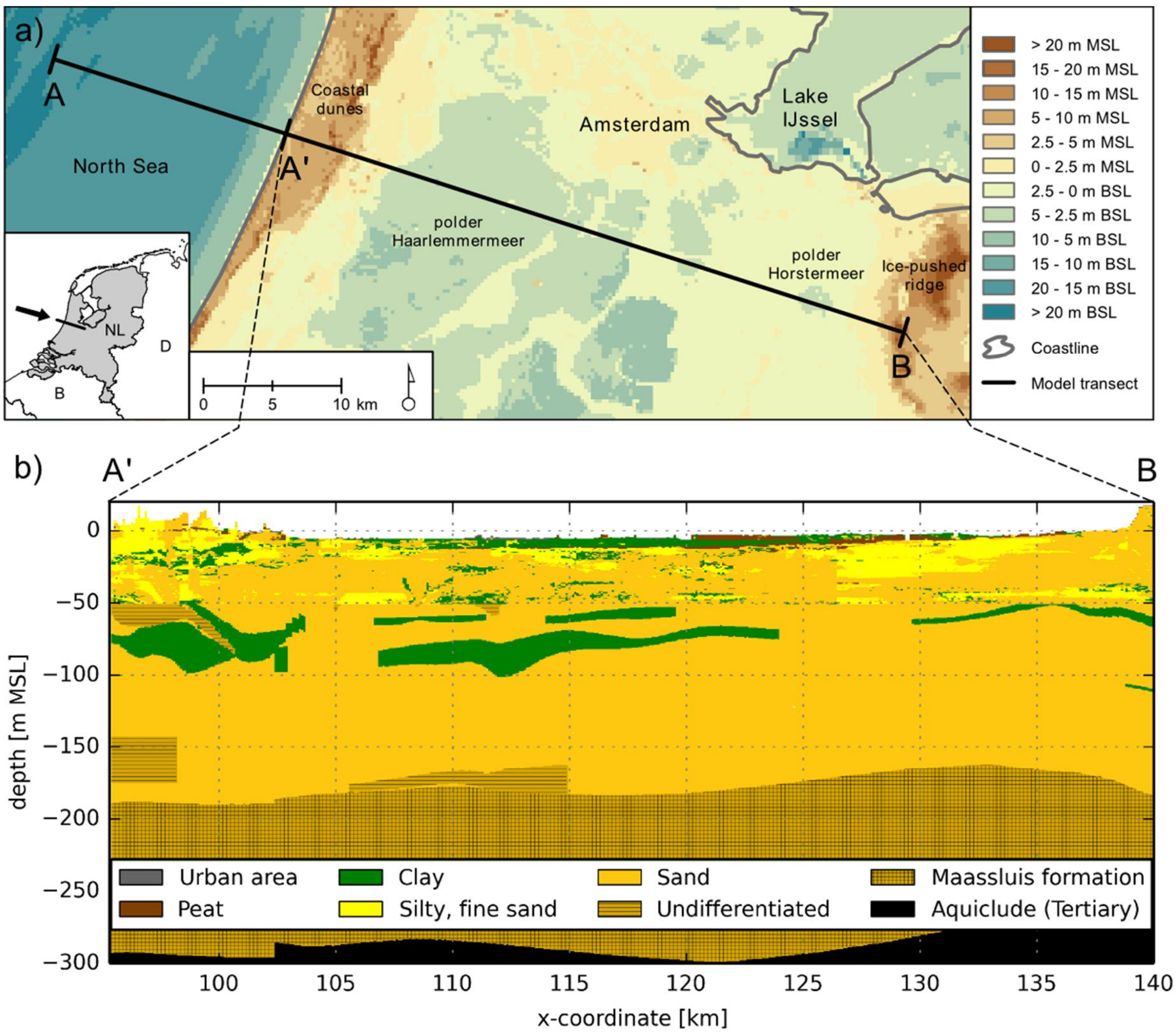

Figure 1. Location of studied transect (A – B), elevation and main topographical features (a), and a lithological cross-section along the transect (A' – B) (b).

Figure 2 – again, please give in colors. I think that a small figure of sea level changes during the whole studied period will be very helpful

We colored Fig 2 and added sea level rise insets to each palaeo-geographical map.

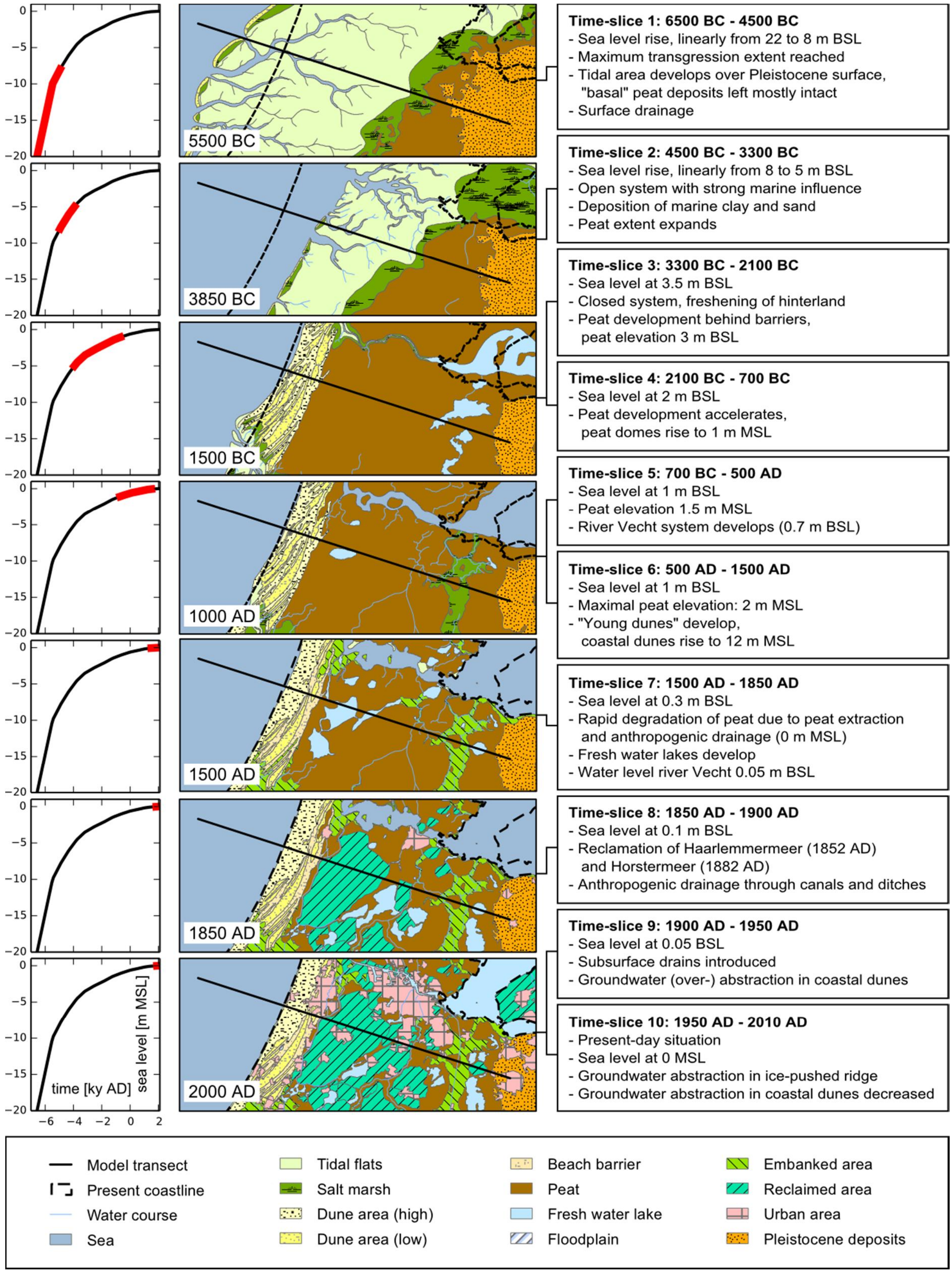

Figure 2. Overview of Holocene palaeo-geographical development (center), sea level rise (left, adapted from Plassche (1982), red curve denotes sea level rise during palaeo-geographical development phase) and description of model time slices (right). For reference, note that the extent of the palaeo-geographical maps equals the extent of Fig. 1a.

Figure 3 – I am not sure that averages are good in this case. If there are big variations with time, then it seems better to give data from specific times.

We specifically chose to compare model results with averages of measured head time series, as we did not model the short-term weather variations reflected in the variations around the measured averages. The chosen time period (1990-2010) was short enough to not include overly large changes to boundary conditions, and long enough to average out weather effects. We therefore respectfully disagree with the reviewer and will leave Fig 3. as is.

Figure 4 – The field data seem to fit the results of the simulation very well which is a great support for this work. Can you elaborate on the locations of disagreement and try to explain them? The effect of the clay layers seems surprisingly small given the fact that you run a transient simulation for not a very long period. Do you have specific data for the configuration and the permeability of these layers? I imagine that a change in these layers (e.g. significantly smaller permeability) will make a difference.

We elaborated the results section on Fig. 4 to include a short discussion on the locations of disagreement. As explained in the methods section, both the location and hydraulic properties are derived from the REGIS database, based on numerous borelogs and conductivity tests on bore samples. Uncertainty is however large, especially in the hydraulic properties, as measured samples range several orders of magnitude in k values, while we used only median values. That is of course also one of the reasons why we present our model as a conceptual tool. We added hydraulic parameters specifically as one of the model simplifications in the Discussion section.

I do not see any evidence for SGD in the lower sub-aquifer. Is there no evidence for relatively fresh groundwater at depth of 100-150 meters near the shore, like there is in some coastal aquifers in other countries? It depends, of course, also on the continuity of the clay layer. Again, it this typical for the whole Dutch coast or specific for this area?

We consider the modeled situation typical for the whole Dutch coast. Drainage and land reclamation caused inland surface elevations to be considerably below MSL. Groundwater flow across the coastline at greater depths is therefore directed inland, contrary to more undulating coastlines in other parts of the world experiencing seaward groundwater flow. We therefore do not expect SGD at depths of around 100-150m. However, in previous periods, SGD is modeled, but not visible in the modeled chloride distribution due to the lack of contrast between the inland brackish/saline water and the sea. It is however visible in Fig. 8, especially 8f. We added a sentence in the results section to highlight this point.

Figure 5 – this seems like a very interesting result and therefore it is a pity that it is not readable, even if I looked at it at 200%. You need to enlarge some of the writing from the work of Stuyfzand. Again, although the comparison is very nice in many cases, it will be nice to elaborate also on the differences. There are some areas that seem without data and still divided to groups – can you explain how this was done? Other data that are not given? Conceptual knowledge? Some of the names are different in (a) and (b) – Is there a reason for that? Can you explain these differences? How did you get the difference in ages?

We colored Fig. 5 and improved its overall readability by removing distracting clutter. We elaborated on the differences in the model validation section, and added the locations of boreholes used in the HYFA analysis to Fig. 5a. The section on HYFA analysis is elaborated to better describe the delineation of hydrosomes. Slight differences in names result from the fact that the origin tracers allow the delineation of more mixing zones than recognized by (Stuyfzand, 1993), e.g., LC/L^{m2}. The differences in ages are determined by the age calculation (Goode, 1996) explained in the modeling section.

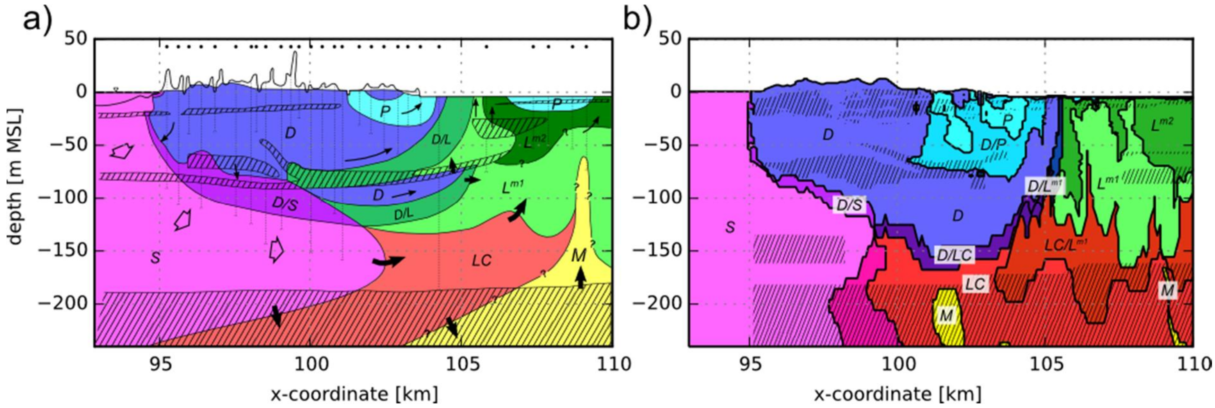

Figure 5. Position of hydrosomes, inferred from hydrochemical facies analysis (adapted from Fig. 4.6 in Stuyfzand (1993)) (a) and from modeled origin tracers (b). Capitals denote discerned hydrosomes: D = Dune (also containing nested artificial recharge hydrosome; not shown), LC = Holocene transgression (L) - Coastal type, Lm1 = L - Ancient Marsh type, Lm2 = L - Young Marsh type, M = Maassluis, P = Polder, S = (actual) North Sea. See Section 2.3 for a description of discerned hydrosomes, and Table 1 for the mapping of origin tracers to hydrosomes.

Figure 6 – What is the salinity of the brown color? I am not sure that I see it in the legend. Is the recharge the same in the whole section? If not, can you show that? It is difficult to see why there are the GH lenses since it is difficult to see the hydraulic heads. You may want to give few inserts of more detailed area in order to show what is missing in the large scale sections.

We checked that all used colors are indeed in the legend. We are not sure what the reviewer means by the brown color, we suspect where an aquitard (shaded area) overlaps the chloride distribution? We extended the legend showing legend items both with and without overlapping ‘aquitard-shading’.

Given the uncertainties surrounding recharge estimates for historic time periods, we opted to apply uniform recharge to the entire model domain, and for the entire modeled period. As stated before, we better explained this in the methods section.

We opted not to show heads for the obvious reason that using heads as a proxy for groundwater flow can be very wrong when dealing with large density differences. Instead, we show the streamfunction in Fig. 6 (and added it to Fig. 8) to visualize flow patterns. We agree with the reviewer that a comparison between the transient model results and the stationary BGH approximation is interesting, and added a line in the results section signifying deviations from the BGH approximation.

Figure 7 – are the SP units the same in the whole model? Why is there a change in SP in 1500? Is the rise in SP in the end a result of pumping?

SP units are the same in the whole model (kg Cl), but we only calculated the SP in the landward side of the model. The (gradual) change in SP after 1500 is caused by anthropogenic alterations to the landscape (drainage and hence land subsidence), causing a landward flux of groundwater over the sea boundary. This rise accelerates after 1850, when the Haarlemmermeer was reclaimed, further lower inland hydraulic heads. Pumping (from 1900 onwards) contributes, but is not the main cause of the increase in SP. We added a line in the results section explaining the rise in SP at 1500 AD.

Figure 8 –I do not see much change in the last 100 years although there were big anthropogenic changes. Did I miss something important? If there are changes, please refer the readers to them (possibly by a more detailed figure)

To start: groundwater flow is a slow process, and solute moves accordingly, even in 100 years. As noted in the results section, the effects of the reclamation of the Haarlemmermeer (the most important anthropogenic change) are effectively limited to the area approximately between x coordinates 103 and 108 km, where the low permeable layer at a depth of around 80 m is absent. Here, upward groundwater flow transported solutes upward at a rate of approximately 0.5 m/y, momentarily slowed down between 1900 and 1950 by the over-extraction in the dune area. Changes are indeed minor where the low permeable layer is present. We emphasized this point in the results section. Note that the upward transport is more clearly visible in the chloride results than in the results for the origin tracers, mainly because of the discrete legend versus the continuous blending legend of Fig. 8, and also differences in dispersion (see added line in discussion).

References

Goode, D. J.: Direct simulation of groundwater age, Water Resour. Res., 32(2), 289–296, 1996.

Kooi, H., Groen, K. and Leijnse, a.: Modes of seawater intrusion during transgressions, Water Resour. Res., 36(12), 3581–3589, doi:10.1029/2000WR900243, 2000.

Van Loon, A. H., Schot, P. P., Griffioen, J., Bierkens, M. F. P. and Wassen, M. J. J.: Palaeo-hydrological reconstruction of a managed fen area in The Netherlands, J. Hydrol., 378(3-4), 205–217, doi:10.1016/j.jhydrol.2009.09.014, 2009.

Lu, C., Kitanidis, P. K. and Luo, J.: Effects of kinetic mass transfer and transient flow conditions on widening mixing zones in coastal aquifers, Water Resour. Res., 45(W12402), 1–17, doi:10.1029/2008WR007643, 2009.

Van der Meulen, M., Doornenbal, J., Gunnink, J. L., Stafleu, J., Schokker, J., Vernes, R. W., Van Geer, F. C., Van Gessel, S. F., Van Heteren, S., Van Leeuwen, R. J. W., Bakker, M. A. J., Bogaard, P. J. F., Busschers, F. S., Griffioen, J., Gruijters, S. H. L. L., Kiden, P., Schroot, B. M., Simmelink, H. J., Van Berkel, W. O., Van der Krogt, R. A. A., Westerhoff, W. E. and Van Daalen, T. M.: 3D geology in a 2D country: perspectives for geological surveying in the Netherlands, Netherlands J. Geosci. / Geol. en Mijnb., 92(4), 217–241, 2013.

Post, V. E. A.: Groundwater salinization processes in the coastal area of the Netherlands due to transgressions during the Holocene, PhD thesis, Faculty of Earth Sciences, VU University Amsterdam, 154 pp., 2004.

Post, V. E. A. and Kooi, H.: Rates of salinization by free convection in high-permeability sediments: insights from numerical modeling and application to the Dutch coastal area, Hydrogeol. J., 11(5), 549–559, doi:10.1007/s10040-003-0271-7, 2003.

Stuyfzand, P. J.: Hydrochemistry and hydrology of the coastal dune area of the Western Netherlands, PhD thesis, Faculty of Earth Sciences, VU University Amsterdam, 362 pp., 1993.

Vernes, R. W. and Van Doorn, T. H. M.: Van Gidslaag naar Hydrogeologische Eenheid - Toelichting op de totstandkoming van de dataset REGIS II, TNO report, Netherlands Inst. of Applied Geoscience TNO, Utrecht, the Netherlands, 2005.

Weerts, H. J. T., Westerhoff, W. E., Cleveringa, P., Bierkens, M. F. P., Veldkamp, J. G. and Rijsdijk, K. F.: Quaternary geological mapping of the lowlands of The Netherlands, a 21st century perspective, Quat. Int., 133-134, 159–178, doi:10.1016/j.quaint.2004.10.011, 2005.

Zheng, C.: Recent Developments and Future Directions for MT3DMS and Related Transport Codes, Ground Water, 47(5), 620–625, doi:10.1111/j.1745-6584.2009.00602.x, 2009.

Reply to comments by reviewer 2 on "Palaeo-modeling of coastal salt water intrusion during the Holocene: an application to the Netherlands" by J. R. Delsman et al.

We thank reviewer 2 for his/her kind words and helpful suggestions. Questions raised by the reviewer are in bold face, our answers in regular face.
On behalf of all coauthors,

Joost Delsman

General comment

The manuscript " Palaeo - modeling of coastal salt water intrusion during the Holocene: an application to the Netherlands" is an interesting study which shows that the existing groundwater salinity in a coastal aquifer is not only the result of the current state of the system, but can be significantly influenced by its recent geological history. Besides showing an interesting case, supported by extensive data, manuscript is well illustrated by what it is, overall, a very attractive paper; however, it has aspects that must be corrected or treated further before publication. Therefore, I would recommend this paper for publication in HESS but only after major changes to manuscript.

We thank reviewer 2 again for his/her kind words and helpful suggestions and will do our best to improve our paper accordingly.

1. Treats many issues of the same subject (evolution of salinity during the Holocene in a coastal aquifer in Netherland) which, in some cases, are not sufficiently clear because the information provided by the authors is insufficient for reader understanding. For example, there is insufficient information in the following sections: description of the study area, parameters and boundary conditions of the mathematical model, hydrochemical conditions selected for the hydrochemical analysis...

We added the requested information to the manuscript; details are provided in our answers to the specific reviewer comments regarding these issues.

2. The structure of the manuscript is deficient: the description and the geological setting of the study area are included in the methodology chapter, the sensitivity analysis of the model should be located before model validation ... Within the sections also there are mixture of different themes. For example, section 3.2 is repetitive and treats in a mixed way the evolution of groundwater salinity and the total amount of salt present in the model, both of which should be treated separately to facilitate the reader understanding.

We re-structured the indicated parts of the manuscript, further details are provided in our answers to the specific reviewer comments regarding these issues.

3. The author is too meticulous in some sections which might be simplified to improve of the reader understanding. For example, Figures 2 and 6 should be more simplified and the Holocene palaeo - geographic development and the evolution of groundwater salinity chapters.

We shortened and simplified Figs 2 and 6, and the chapter on the evolution of groundwater salinity. Again, details are provided in our answers to the specific reviewer comments regarding these issues.

Another aspect that the author should address deeper is the eastern side boundary condition of the study area. The mathematical model has been made with a closed boundary throughout the period studied. Ie, through that limit has not been produced freshwater input in the 8500 years modeled. This is critical in the evolution of salt washing that has occurred since the 6500 BC transgression. The authors consider a limit of no flow due to the existence of a groundwater divide whose regional character is not sufficiently justified. Just as it has remained unchanged throughout the period considered. If through this limit occurs or has occurred freshwater input, the paper conclusions would not be valid.

The elevated position of the ice-pushed ridge within its low-relief surroundings (on both its western and eastern side) ensures the role of the ice-pushed ridge as a groundwater divide over the entire profile depth. Results of the nation-wide groundwater model of the Netherlands (De Lange et al., 2014) indicate a negligible flux crossing the ice-pushed ridge and support this choice of boundary condition. The important landscape features that define the large scale flow patterns all predate the model period, they have been in place since the Saalien (150 ky BP). We better motivated our choice of boundary condition in the manuscript.

Specific comments

Abstract

The abstract is too general. The sentences of generic character should be reduced and concrete results obtained in this paper should be added.

We pretty much completely revised the abstract and included more specific results.

Methods

Paragraph "Study area and Holocene palaeo-geographical development" should not be included in Methods, but should be a separate chapter of description of the study area.

We moved the description of the study area and its palaeo-geographical development to a separate chapter.

The authors considered a dividing of regional flow in the eastern side due to the recharge that occurs in the ice - pushed ridge. However, given the depth of the aquifer in this area is greater than 200 m and the existence of levels of low hydraulic conductivity about 50 m b.s.l., I do not find it difficult to believe the existence of a shallow local flow with a divide in this position and a deeper regional flow with a general EW component. Has this situation changed over time? This subject would have great impact on the salt washing that has occurred over time.

See response under General comment 3.

This section (description of the study area) should include any information about Maassluis formation due its significance in the evolution of the groundwater salinity of the aquifer.

We included more specific information on the Maassluis formation: “The Maassluis formation comprises the oldest Pleistocene deposits and includes sandy and clayey sediments of marine origin, limited dated samples indicate remaining connate marine groundwater (Post et al., 2003).”

Further explanation would be necessary about the infiltration scheme used since 1957 in the study area.

We added a line to the manuscript explaining the infiltration scheme used since 1957.

<u>**Palaeo‐hydrogeological modelling**</u>

Please, consider adding a figure to represent the conceptual model used in mathematical modeling with the different boundary conditions considered.

We added a conceptual figure containing the boundary conditions and, whenever possible, parameter values used.

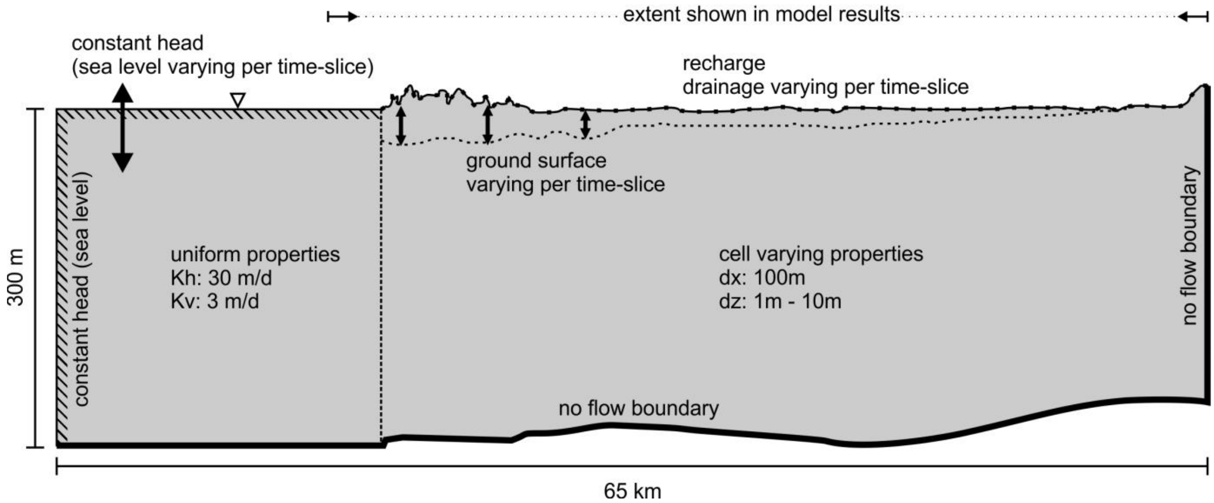

Figure 3. Conceptual model representation.

As I said earlier, the eastern side boundary condition should be addressed in more depth by the authors.

See response under General comment 3.

What section has been modeled, the transect AB or the A'‐B?

We modeled the entire transect AB, we clarified this in the manuscript.

From sentence found on lines 18 and 19 of page 13713, is understood that the Maassluis formation occupies the entire edge.

For the landward part of the transect (A’-B), the Maassluis formation indeed spans the entire bottom edge. On the seaward side of the transect, however, geohydrological information is scarce. We therefore modeled the seaward side as one homogeneous aquifer. We clarified this in the manuscript.

K and S values used in modeling should be provided.

We used cell-specific K values in our modeling, based on the national geohydrological databases of the Netherlands (REGIS and GEOTOP), we clarified this in the manuscript. It was therefore impossible to provide the used K values in the manuscript. Given the long time scales considered, we modeled flow as steady state and therefore did not use storativities.

Why authors speak of time slices and not of stress periods?

The term time slice denotes a period with a distinct (palaeo-) geographical signature. Stresses (and therefore stress periods) can vary within a time slice. The rapidly rising sea level in the first two time slices necessitated the use of several stress periods in modeling. We added a line to the manuscript noting that time slices 1 and 2 contain several stress periods, all others contain just one.

<u>Hydrochemical facies analysis</u>

Authors should describe in more detail the characteristics of different hydrochemical zones considered in the study. In this sense, it would be interesting to complete the table I with more hydrochemical information.

We extended the section on the Hydrochemical Facies Analysis with more detail regarding the geochemical parameters used.

What is the difference between recharge and surface water in Table I?

The origin tracer Recharge enters the model as recharge (RCH package), Surface water as infiltrating surface water (losing streams, RIV package) (see Table 1).

<u>Model validation</u>

It is desirable that the authors indicate the number of points used for model validation and also add their location in Figure 1.

We added the number of validation points and their locations to Fig 1.

RMSE values (head and concentration) should be given in% for knowing the degree of mathematical model validity without having to check the range of variation of these parameters in the study area.

We reported normalized RMSE values in the manuscript.

<u>Evolution of groundwater salinity</u>

This section is very confusing and, in some cases, repetitive. Authors should simplify and structure more. Speaking, first, about the evolution of the salinity based on Figure 6, that should contain less phases and should coincide with the different phases seen in Figure 2 (it should also be simplified), then of the Total SP based on Figure 7 and, finally, of the evolution of water types considered. Authors should not intermix the different topics.

We reduced the number of phases shown in Figs 2, 6 and 8, moved the description of all time slices to a new table, and re-structured the Results section to separate the different topics and improve overall clarity.

From reading the text is deducted the river Vecht is a gaining stream and this should be made clearer.

The reviewer is correct; we clarified this in the manuscript.

<u>Sensitivity runs</u>

This section should come before the section on model validation.

We moved the section on the sensitivity runs to precede model validation.

<u>Figure 1</u>

Please, in the legend include the age of the materials.

To include more information on the age of the deposits, we added the Holocene / Pleistocene delineation in Fig 1 and added 'Tertiary' to indicate the age of the aquiclude.

The different frames of the legend are not easily distinguished. It would be better to use different colors.

We followed the reviewer's suggestion and colored Fig 1.

What kind of rock is "heterogenous"?

'Heterogeneous' in Fig 1 denotes not further lithologically differentiated formation members of the geological classification used by the Geological Survey of the Netherlands, due to a lack of borehole information. Hydraulic parameters are however assigned to these formations by the Netherlands Geological Survey (Van der Meulen et al., 2013; Vernes and Van Doorn, 2005; Weerts et al., 2005). We changed the label from 'heterogeneous' to 'undifferentiated' in Fig 1b to avoid confusion.

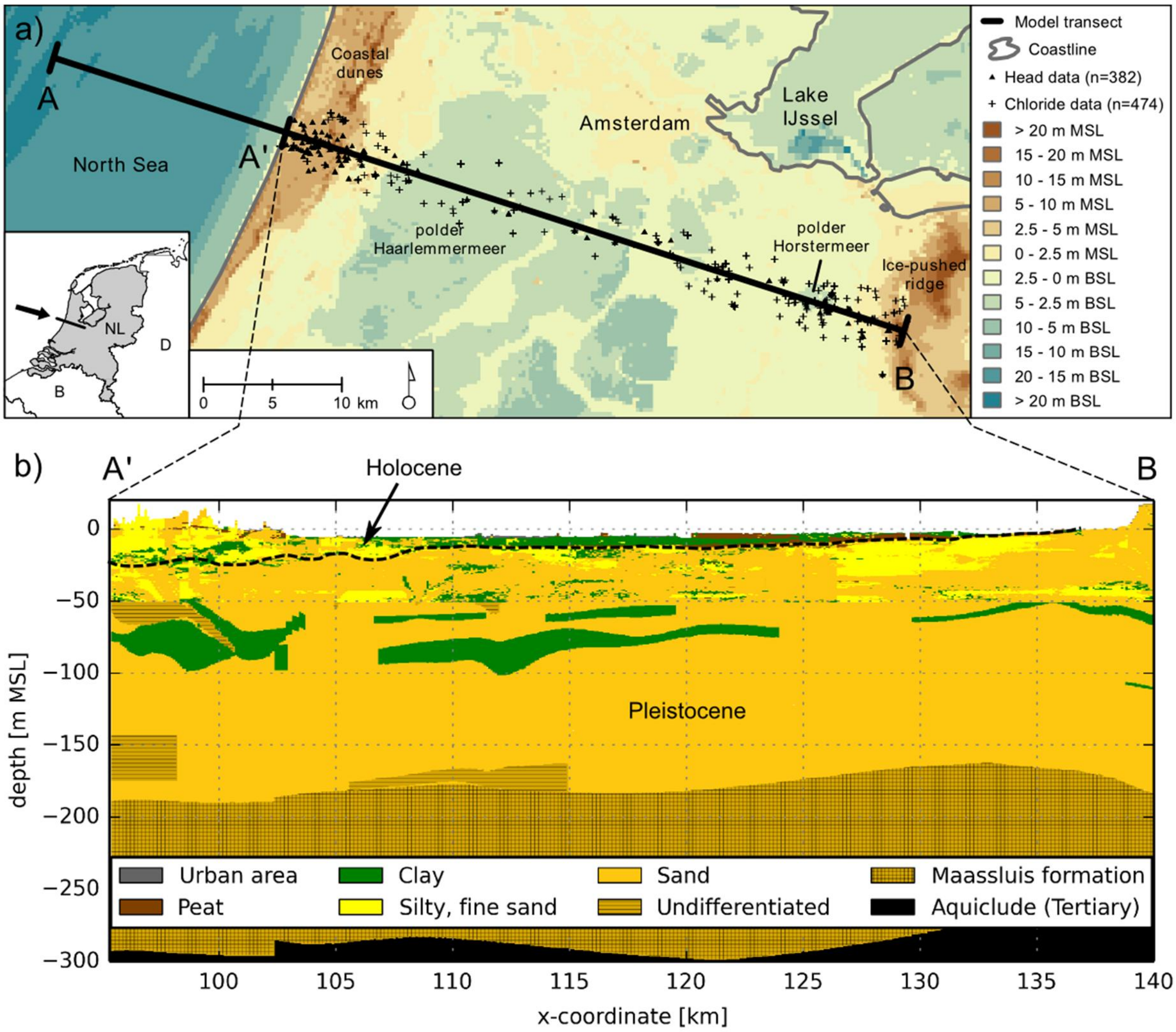

Figure 1. Location of studied transect (A – B), elevation and main topographical features (a), and lithological cross-section along the transect (A' – B) (b), dashed line in (b) demarcates Pleistocene and Holocene deposits.

Figure 2

I recommend simplifying the text shown in the different stages, leaving an explanatory chart by stage considered.

We revised Fig 2 to include one less period, moved the time slice description to a separate (new) table, and included information on sea level rise.

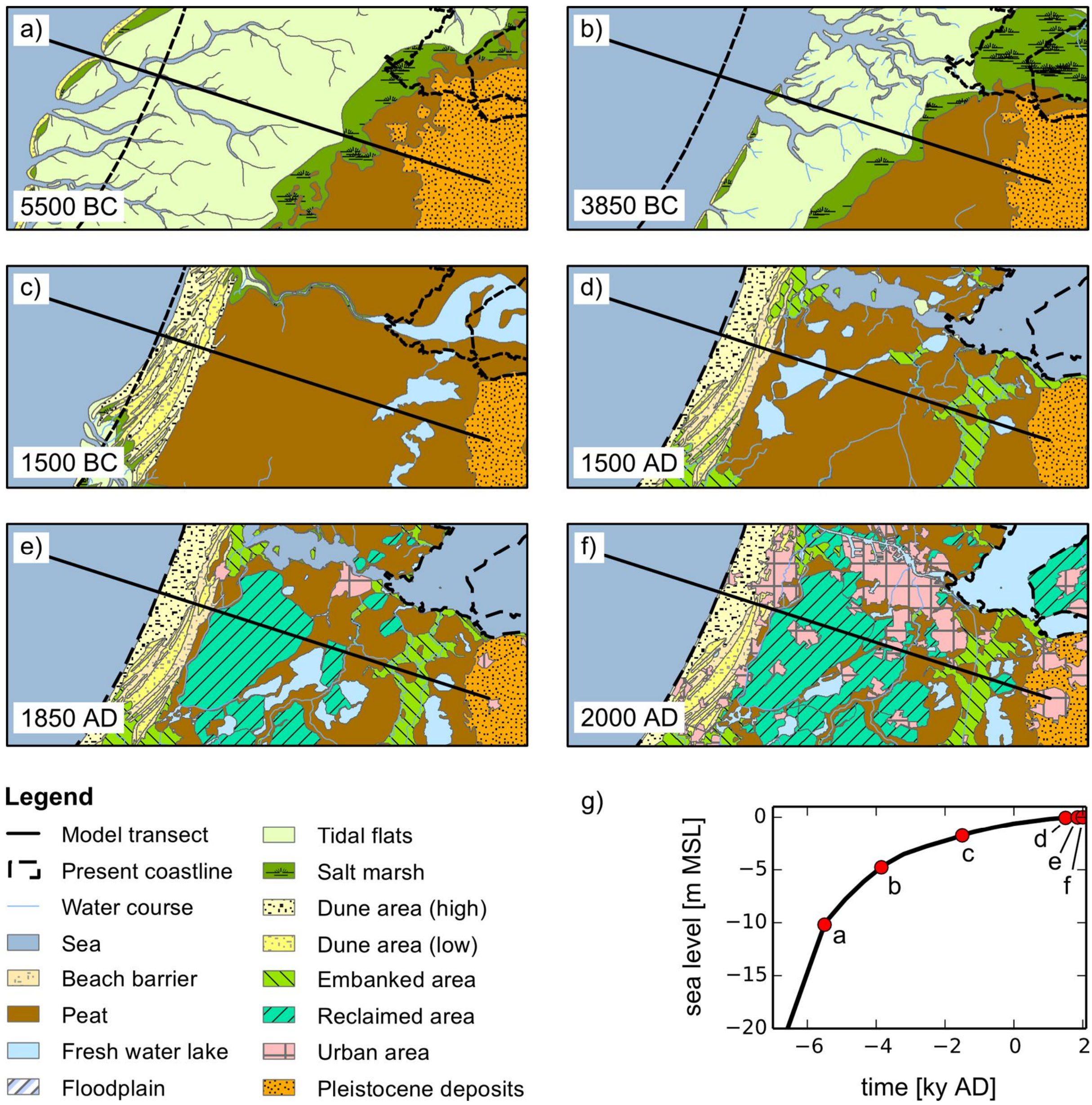

Figure 2. Overview of Holocene palaeo-geographical development (a-f) and sea level rise (g, adapted from Plassche (1982)). Red dots and letters in g) refer to corresponding palaeo-geographical maps a-f. For reference, note that the extent of the palaeo-geographical maps equals the extent of Figure 1a.

Figure 6

Please, add the x axis in the right column. It would be interesting that graphs coincide with moments shown in Figure 2. Please, locate in the graphs the position of the coastline in each of the moments. Please, locate in the graphs areas with pumping, river and lakes

We simplified Fig 6 (and 8) to include only those moments coinciding with the palaeo-geographical maps in Fig 2 and added explanatory information.

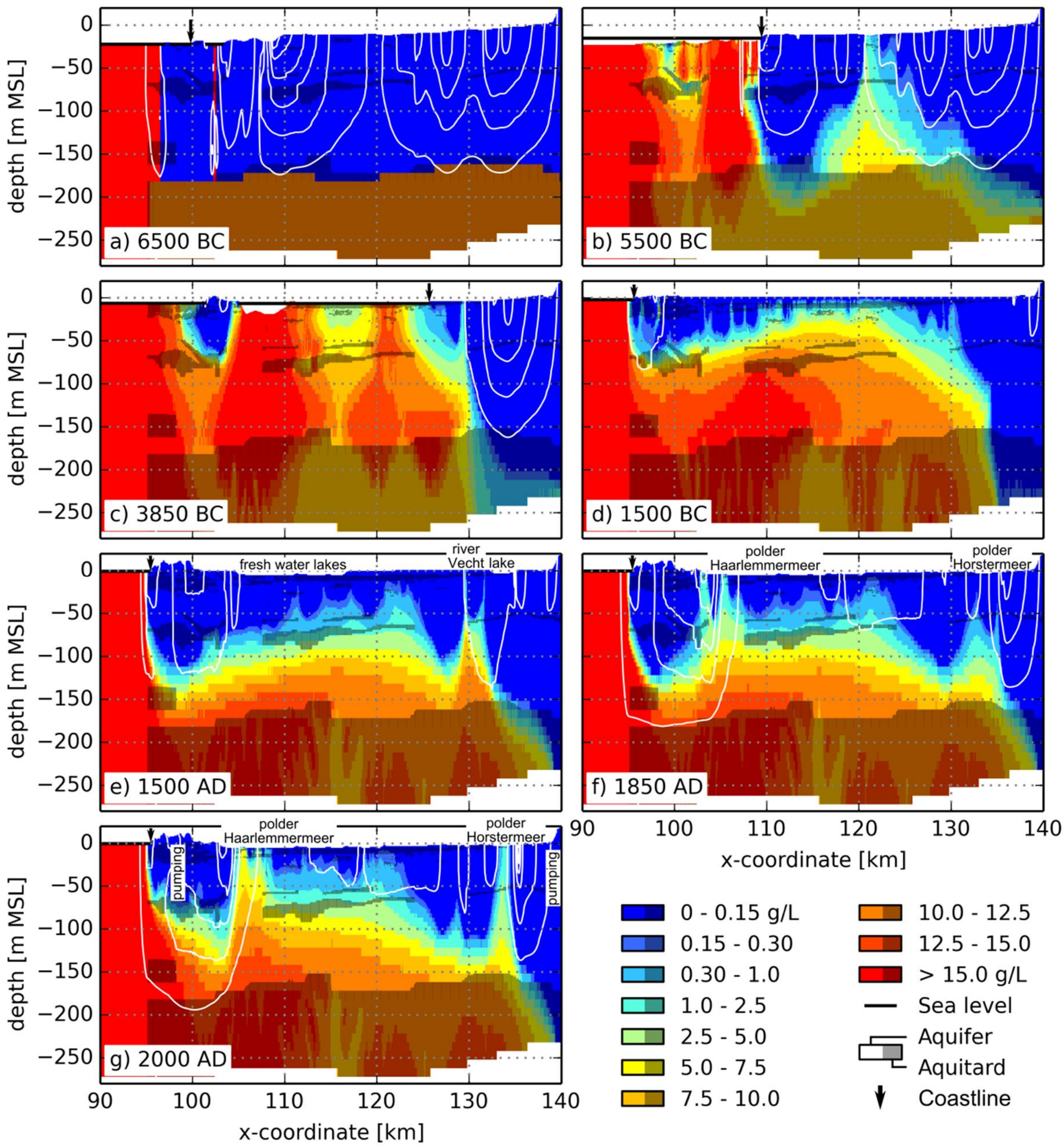

Figure 7. Modeled evolution of groundwater chloride concentration (a – g). White lines are contours of the stream function, contour intervals are equal for all time slices. Except for a) (starting concentration), transect times correspond to palaeo-geographical maps in Figure 2.

References

De Lange, W. J., Prinsen, G. F., Hoogewoud, J. C., Veldhuizen, A. A., Verkaik, J., Oude, G. H. P., Walsum, P. E. V. Van, Delsman, J. R., Hunink, J. C., Massop, H. T. L. and Kroon, T.: An operational, multi-scale, multi-model system for consensus-based, integrated water management and policy analysis: The Netherlands Hydrological Instrument, Environ. Model. Softw., 59, 98–108, doi:10.1016/j.envsoft.2014.05.009, 2014.

Van der Meulen, M., Doornenbal, J., Gunnink, J. L., Stafleu, J., Schokker, J., Vernes, R. W., Van Geer, F. C., Van Gessel, S. F., Van Heteren, S., Van Leeuwen, R. J. W., Bakker, M. A. J., Bogaard, P. J. F., Busschers, F. S., Griffioen, J., Gruijters, S. H. L. L., Kiden, P., Schroot, B. M., Simmelink, H. J., Van Berkel, W. O., Van der Krogt, R. A. A., Westerhoff, W. E. and Van Daalen, T. M.: 3D geology in a 2D country: perspectives for geological surveying in the Netherlands, Netherlands J. Geosci. / Geol. en Mijnb., 92(4), 217–241, 2013.

Post, V. E. A., Plicht, H. and Meijer, H.: The origin of brackish and saline groundwater in the coastal area of the Netherlands, Netherlands J. Geosci. / Geol. en Mijnb., 82(2), 133–147, 2003.

Vernes, R. W. and Van Doorn, T. H. M.: Van Gidslaag naar Hydrogeologische Eenheid - Toelichting op de totstandkoming van de dataset REGIS II, TNO report, Netherlands Inst. of Applied Geoscience TNO, Utrecht, the Netherlands, 2005.

Weerts, H. J. T., Westerhoff, W. E., Cleveringa, P., Bierkens, M. F. P., Veldkamp, J. G. and Rijsdijk, K. F.: Quaternary geological mapping of the lowlands of The Netherlands, a 21st century perspective, Quat. Int., 133-134, 159–178, doi:10.1016/j.quaint.2004.10.011, 2005.

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Creation date: August 12, 2014

Overview of changes to manuscript "Palaeo-modeling of coastal salt water intrusion during the Holocene: an application to the Netherlands"

Page	Line	Type	What has been inserted or deleted	Author	Date
1	5	Inserted	,3	Joost Delsman	05-26-2014
2	2	Inserted	Coastal groundwater reserves often reflect a complex evolution of marine transgressions and regressions, and are only rarely in equilibrium with current boundary conditions. Understanding and managing the present-day distribution and future development of these reserves and their hydrochemical characteristics therefore requires insight in their complex evolution history.	Joost Delsman	05-05-2014
2	6	Deleted	Management of coastal fresh groundwater reserves requires a thorough understanding of the present-day groundwater salinity distribution and its possible future development. However, coastal groundwater often still reflects a complex history of marine transgressions and regressions, and is only rarely in equilibrium with current boundary conditions. In addition, the distribution of groundwater salinity is virtually impossible to characterize satisfactorily, complicating efforts to model and predict coastal groundwater flow. A way forward may be to account for the historical development of groundwater salinity when modeling present-day coastal groundwater flow.	Joost Delsman	05-05-2014
2	14	Inserted	, together with groundwater age and origin calculations,	Joost Delsman	05-26-2014
2	15	Inserted	, study and evaluate	Joost Delsman	05-26-2014
2	16	Inserted	the last 8.5 ky of	Joost Delsman	05-26-2014
2	16	Deleted	perceptual	Joost Delsman	05-01-2014
2	17	Inserted	conceptual	Joost Delsman	05-01-2014
2	18	Inserted	Throughout the modeled period, coastal groundwater distribution never reached equilibrium with contemporaneous boundary conditions. This result highlights the importance of historically changing boundary conditions in shaping the present-day distribution of groundwater and its chemical composition. As such, it acts as a warning against the common use of a steady-state situation given	Joost Delsman	05-05-2014

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			present-day boundary conditions to initialize groundwater transport modeling in complex coastal aquifers or, more general, against explaining existing groundwater composition patterns from the currently existing flow situation. The importance of historical boundary conditions not only holds true for the effects of the large-scale marine transgression around 5 ky BC thoroughly reworking groundwater composition, but also for the more local effects of a temporarily present gaining river still recognizable today.		
2	28	Inserted	further	Joost Delsman	05-05-2014
3	30	Inserted	We found free convection to drive large scale fingered infiltration of sea water to depths of 200 m within decades after a marine transgression, displacing the originally present groundwater upwards. Subsequent infiltration of fresh meteoric water was in contrast hampered by the existing density gradient. We observed discontinuous aquitards to exert a significant control on infiltration patterns and the resulting evolution of groundwater salinity.	Joost Delsman	05-05-2014
3	2	Deleted	Not once reaching steady-state throughout the Holocene, our results demonstrate the long term dynamics of salinity in coastal aquifers. This stresses the importance of accounting for the historical evolution of coastal groundwater salinity when modeling present-day coastal groundwater flow, or when predicting impacts of e.g. sea level rise on coastal aquifers. Of more local importance	Joost Delsman	05-05-2014
3	7	Inserted	Finally, adding to a long-term scientific debate on the origins of groundwater salinity in Dutch coastal aquifers	Joost Delsman	05-05-2014
3	8	Deleted	findings	Joost Delsman	05-01-2014
3	8	Inserted	modeling results	Joost Delsman	05-01-2014
3	10	Inserted	Though conceptual, comprehensively modeling the Holocene evolution of groundwater salinity, age and origin offered a unique view on the complex processes shaping groundwater in coastal aquifers over millennial time scales.	Joost Delsman	05-26-2014
3	13	Deleted	The implications of our results extend beyond understanding the present-day	Joost Delsman	05-05-2014

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			distribution of salinity, as the proven complex history of coastal groundwater also holds important clues for understanding and predicting the distribution of other societally relevant groundwater constituents.		
4	11	Deleted	Although the “classic” saltwater intrusion (SI) process, i.e., the development of a landward protruding saline groundwater wedge under the influence of groundwater density differences has been studied extensively in the past, above	Joost Delsman	05-05-2014
4	14	Inserted	Above	Joost Delsman	05-05-2014
4	14	Inserted	in the “classic” saltwater intrusion process, i.e., the development of a landward protruding saline groundwater wedge under the influence of groundwater density differences	Joost Delsman	05-05-2014
5	24	Inserted	(Section 2)	Joost Delsman	05-05-2014
6	7	Deleted	Methods	Joost Delsman	05-05-2014
6	7	Inserted	Site description	Joost Delsman	05-05-2014
6	8	Deleted	and Holocene palaeo-geographical development	Joost Delsman	05-06-2014
6	17	Deleted	and	Joost Delsman	05-02-2014
6	17	Inserted	,	Joost Delsman	05-02-2014
6	18	Deleted	net	Joost Delsman	05-02-2014
6	18	Inserted	total	Joost Delsman	05-02-2014
6	18	Inserted	of 840 mm,	Joost Delsman	05-02-2014
6	18	Deleted	surplus (precipitation minus	Joost Delsman	05-02-2014
6	18	Inserted	and an average annual Makkink reference	Joost Delsman	05-02-2014
6	19	Inserted	transpi	Joost Delsman	05-02-2014
6	19	Inserted	total	Joost Delsman	05-02-2014
6	19	Deleted	)	Joost Delsman	05-02-2014
6	19	Inserted	(Makkink, 1957)	Joost Delsman	05-02-2014
6	19	Deleted	250	Joost Delsman	05-02-2014
6	19	Inserted	590	Joost Delsman	05-02-2014
6	23	Inserted	The Maassluis formation comprises the oldest Pleistocene deposits and includes	Joost Delsman	07-02-2014

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			sandy and clayey sediments of marine origin, limited dated samples indicate remaining connate marine groundwater (Post et al., 2003).		
7	4	Inserted		Joost Delsman	05-06-2014
			Holocene palaeo-geographical development		
7	13	Deleted	(Fig. 2)	Joost Delsman	07-04-2014
7	30	Inserted	, whereby water is infiltrated in infiltration ponds and extracted using recovery canals and horizontal drains.	Joost Delsman	07-02-2014
7	31	Deleted	.	Joost Delsman	07-02-2014
7	31	Inserted		Joost Delsman	05-05-2014
8	2	Inserted	to	Joost Delsman	05-26-2014
8	3	Deleted	-	Joost Delsman	05-26-2014
8	4	Inserted	(locations and depths in Figure 6a)	Joost Delsman	05-22-2014
8	5	Inserted	(with many more data from monitor wells along the Dutch coast)	Stuyfzand, Pieter	05-11-2014
8	9	Inserted	following	Stuyfzand, Pieter	05-11-2014
8	9	Inserted	,	Stuyfzand, Pieter	05-11-2014
8	9	Deleted	,	Stuyfzand, Pieter	05-11-2014
8	9	Inserted	in order of increasing salinity: (i) fresh dune groundwater (rainwater infiltrated in coastal dunes)	Stuyfzand, Pieter	05-11-2014
8	10	Inserted	(D in Figure 6)	Joost Delsman	05-16-2014
8	10	Inserted	, (ii) fresh, artificially recharged Rhine River water, (iii) slightly brackish polder water (a mix of rainwater, Rhine River water and exfiltrated Holocene transgression water, which after mixing infiltrated via canals and ditches on a higher topographical level than the deep polders from which the mix originated	Stuyfzand, Pieter	05-11-2014
8	13	Inserted	(P)	Joost Delsman	05-16-2014
8	13	Inserted	, (iv) 2 types of brackish groundwater, which infiltrated during the Holocene transgression	Stuyfzand, Pieter	05-11-2014
8	14	Inserted	(LC/Lm)	Joost Delsman	05-16-2014
8	15	Inserted	, (v) brackish to saline palaeogroundwater upconing from deep marine Tertiary	Stuyfzand, Pieter	05-11-2014

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			aquitards		
8	16	Inserted	(M)	Joost Delsman	05-16-2014
8	16	Inserted	, and (vi) intruding North Sea water	Stuyfzand, Pieter	05-11-2014
8	16	Inserted	(S) (Figure 6a)	Joost Delsman	05-16-2014
8	16	Inserted	. Within each hydrosome a variety of hydrochemical facies was discerned by	Stuyfzand, Pieter	05-11-2014
8	17	Deleted	while a	Stuyfzand, Pieter	05-11-2014
8	17	Inserted	4 aspects: (a) the redox level, as deduced from the concentrations of O2, NO3, SO4, Fe, Mn and CH4; (b) the calcite saturation index; (c) a pollution index (POLIN) based on 6 equally weighted quality aspects; and (d) the Base EXchange index (BEX), defined as the sum of the cations Na, K, and Mg (in meq/L), corrected for a contribution of sea salt.	Stuyfzand, Pieter	05-11-2014
8	21	Deleted	redox, pollution and base exchange indices distinguished the hydrochemical zones	Stuyfzand, Pieter	05-11-2014
8	22	Deleted		Joost Delsman	05-22-2014
8	22	Inserted		Stuyfzand, Pieter	05-11-2014
8	23	Inserted		Joost Delsman	05-05-2014
8	24	Deleted		Joost Delsman	05-06-2014
8	28	Inserted	(A-B in Fig. 1a, conceptual outline in Figure 3)	Joost Delsman	07-02-2014
8	30	Inserted	top of Tertiary clays	Joost Delsman	05-02-2014
8	31	Deleted	bottom	Joost Delsman	05-02-2014
8	31	Inserted	(below	Joost Delsman	05-02-2014
8	31	Deleted	of	Joost Delsman	05-02-2014
8	31	Inserted	, Fig. 1b)	Joost Delsman	05-02-2014
9	32	Inserted	The assumption of no-flow on the eastern side is motivated by the elevated position of the ice-pushed ridge in its surroundings during the entire modeled period and is supported by model results of the national groundwater model of the Netherlands (De Lange et al., 2014).	Joost Delsman	07-02-2014

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9	4	Inserted	model	Joost Delsman	05-26-2014
9	5	Inserted	Cell-specific	Joost Delsman	07-02-2014
9	6	Deleted	Geohydrological	Joost Delsman	07-02-2014
9	6	Inserted	geohydrological	Joost Delsman	07-02-2014
9	8	Inserted	http://www.dinoloket.nl	Joost Delsman	05-06-2014
9	8	Inserted	. GEOTOP provides detailed (100x100x0.5m) estimates of lithology to a depth of 50 m,	Joost Delsman	05-06-2014
9	9	Deleted	,	Joost Delsman	05-06-2014
9	9	Inserted	we applied REGIS-derived formation-specific hydraulic properties for the deeper subsurface. We assumed a homogeneous aquifer seaward of the present coastline, given the limited availability of geohydrological information.	Joost Delsman	05-06-2014
9	12	Deleted	information	Joost Delsman	05-06-2014
9	12	Inserted	Information	Joost Delsman	05-06-2014
9	14	Inserted	We used chloride to represent salinity, as chloride is the dominant anion in Dutch coastal groundwater and density is linearly related to it within naturally occurring concentrations. To better understand the evolution of groundwater salinity, we included several fictitious inert tracers, representing the various inputs to the groundwater system, as additional mobile species in the simulation. These tracers were given a concentration of one when they entered the model domain, or were present during model start. We refer to these fictitious tracers as origin tracers in the remainder of this paper. Furthermore, we modeled direct groundwater age (Goode, 1996) by including an additional specie with a negative zero-th order decay term (Zheng, 2009). This specie is zero when entering the model domain, then gains one for every year spent inside the model. An overview of the different origin tracers and their relation to hydrosomes (Section 2.3) is presented in Table 1.	Joost Delsman	07-02-2014
9	30	Deleted	to all model cells	Joost Delsman	05-26-2014
9	33	Deleted	perceptual	Joost Delsman	05-02-2014

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9	33	Inserted	conceptual	Joost Delsman	05-02-2014
10	3	Inserted		Joost Delsman	05-26-2014
10	3	Deleted		Joost Delsman	05-05-2014
10	3	Inserted	2.3	Joost Delsman	05-05-2014
10	3	Deleted	2.3	Joost Delsman	05-05-2014
10	8	Inserted	, Table 2	Joost Delsman	07-04-2014
10	10	Inserted	(implemented using ten stress periods)	Joost Delsman	07-02-2014
10	11	Inserted	(transgression phase)	Joost Delsman	05-03-2014
10	12	Inserted	; model cells not present in a previous time slice were given the state of the previously uppermost model cell per column.	Joost Delsman	05-06-2014
10	14	Deleted	.	Joost Delsman	05-06-2014
10	17	Inserted	Table 3	Joost Delsman	07-04-2014
10	17	Inserted	In addition to reconstructed larger-scale drainage structures as e.g. the river Vecht, we applied infinite drainage at the model surface to represent small streams and creeks.	Joost Delsman	05-02-2014
10	26	Inserted		Joost Delsman	07-04-2014
10	28	Deleted	7000	Joost Delsman	05-26-2014
10	28	Inserted	7 k	Joost Delsman	05-26-2014
10	29	Inserted	uniform	Joost Delsman	05-02-2014
10	29	Inserted	of 0.7 mm/d	Joost Delsman	05-02-2014
10	30	Inserted	We did not differentiate recharge amounts for vegetation types, given the lack of data on past vegetation patterns.	Joost Delsman	05-02-2014
11	9	Deleted	reference	Joost Delsman	07-04-2014
11	13	Deleted		Joost Delsman	05-16-2014
12	25	Inserted	Sensitivity runs SEAWAT model run time simulating 8.5 ky and including seven additional mobile species was approximately 3 days on a standard single cpu, no convergence	Joost Delsman	07-04-2014

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			problems were encountered including at time-slice transitions. The performed sensitivity runs did not reveal a significant influence of dispersivity on the general shape of the present-day salinity distribution. A tenfold decrease in dispersivity did, however, result in a narrower transition zone between fresh and saline groundwater, most importantly beneath the coastal dunes (100 m to 25 m). Further inland, the width of the transition zone decreased from around 50 m to around 25 m. While measurements indicate a narrow transition zone beneath the coastal dunes, they suggest a wide transition zone further inland and are therefore inconclusive in regards to the “better” value. The Maassluis sensitivity runs revealed a clear dependence of the modeled historical trajectory and present-day location of Maassluis water on its initial chloride concentration. While the general processes acting on this water type remain the same, the extent to which Maassluis water is transported through the subsurface is negatively related to its chloride concentration. At 15 g/L, the density difference between infiltrating transgression water and resident Maassluis water clearly provides less incentive for flow than at 0 g/L. As a result, while a significant fraction of Maassluis water is still present at its original location in the 15 g/L run at model end, it is almost completely displaced in the 0 g/L run, with the 5 g/L and 10 g/L scenarios in between those extremes. Comparison with the HYFA results of Stuyfzand (1993), although based on only limited samples at the relevant depths, suggests an initial Maassluis concentration of around 10 g/L, showing agreement in the relatively shallow occurrence of Maassluis at a depth of 100 m around x-coordinate 112 km.		
12	18	Inserted	382	Joost Delsman	07-02-2014
12	19	Inserted	, locations in Figure 1	Joost Delsman	07-04-2014
12	20	Inserted	absolute	Joost Delsman	07-02-2014
12	21	Inserted	RMSE normalized to the range of observed values (NRMSE) is in both cases 11%.	Joost Delsman	07-02-2014
12	22	Inserted	absolute	Joost Delsman	07-02-2014

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12	23	Deleted	small-scale	Joost Delsman	05-05-2014
12	23	Inserted	large	Joost Delsman	05-05-2014
12	23	Deleted		Joost Delsman	05-05-2014
12	23	Inserted	over short distances	Joost Delsman	05-05-2014
12	25	Deleted	all	Joost Delsman	05-05-2014
12	25	Inserted	factors	Joost Delsman	05-05-2014
12	25	Deleted	only generally included	Joost Delsman	05-05-2014
12	25	Inserted	implemented	Joost Delsman	05-05-2014
12	25	Inserted	only in a simplified way	Joost Delsman	05-05-2014
12	27	Inserted	, NRMSE	Joost Delsman	07-02-2014
12	27	Inserted	, 16%	Joost Delsman	07-02-2014
12	28	Inserted	, 22%	Joost Delsman	07-02-2014
12	28	Inserted	, locations in Figure 1	Joost Delsman	07-04-2014
13	3	Inserted	Discrepancies around x-coordinates 113 and 125 are likely due to the orthogonal projection of chloride measurements on the model transect, and caused by local head gradients not included in the chosen model transect. And while the several tens of meters wide transition zone between fresh and saline water inland is well-captured by the model, the width of the transition zone beneath the BGH lens below the dunes is overestimated by the applied model-wide dispersion parameters.	Joost Delsman	05-06-2014
13	8	Deleted		Joost Delsman	05-06-2014
13	8	Inserted	A comparison of available tritium measurements with the modeled 1952 age contour	Joost Delsman	05-06-2014
13	9	Deleted	The validation of model-derived direct groundwater ages	Joost Delsman	05-06-2014
13	14	Inserted	Age calculation results were omitted from this paper for the sake of brevity, but are included in the film available as supplementary information.	Joost Delsman	05-06-2014
13	17	Deleted	conservative	Joost Delsman	05-06-2014
13	17	Inserted	origin	Joost Delsman	05-06-2014
13	18	Inserted	0	Joost Delsman	08-12-2014

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13	18	Deleted	2.3	Joost Delsman	08-12-2014
13	22	Deleted	Though not exact, the comparison shows a clear correspondence between the position of modeled conservative tracers and hydrosomes discerned by Stuyfzand (1993), in both relatively recent (sea water wedge, infiltrating dune water) and older water types (Maassluis water, and water infiltrated during transgression and after extensive peat formation).	Joost Delsman	05-16-2014
14	26	Inserted	Various discrepancies exist between the distribution of modeled origin tracers and measured distribution of hydrosomes. Discrepancies are largest at depths greater than 150 m BSL beneath the coastal dunes, and below 80 m BSL in the deep polder area. This is due to the depth limits of observation wells (differing in both zones), giving rise to uncertainties in both the hydrochemical, hydraulic and hydrogeological data underlying the HYFA analysis and in the structure of the model. The differences call for further model optimizations where the hydrochemical patterns are very reliable, for instance regarding the advance of the intruding North Sea water, shape of the fresh dune water lens and transition zone below it, and the presence of polder water in the central parts of the deep polder Haarlemmermeer. Overall however, the comparison shows a clear correspondence between the position of modeled origin tracers and hydrosomes, in both relatively recent (sea water wedge, infiltrating dune water) and older water types (Maassluis water, and water infiltrated during transgression and after extensive peat formation).	Joost Delsman	05-16-2014
14	9	Deleted	movie	Joost Delsman	06-13-2014
14	9	Inserted	film	Joost Delsman	06-13-2014
14	9	Deleted	its	Joost Delsman	07-04-2014
14	9	Inserted	the	Joost Delsman	07-04-2014
14	9	Inserted	of chloride, age and origin tracers	Joost Delsman	07-04-2014
14	11	Inserted	model	Joost Delsman	07-04-2014
14	17	Deleted	these	Joost Delsman	07-04-2014

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Page	Line	Type	What has been inserted or deleted	Author	Date
14	19	Deleted	Fig. 6b	Joost Delsman	07-04-2014
14	19	Inserted	Fig. 6c	Joost Delsman	07-04-2014
14	25	Deleted		Joost Delsman	07-04-2014
14	25	Deleted	Once the coastline reached the regional flow system of the ice-pushed ridge (4500 BC), infiltration is hampered over a distance of some kilometers seaward by the exfiltration of this flow system. Termed submarine groundwater discharge, this phenomenon is receiving much attention in recent scientific literature (e.g., Michael et al., 2005; Taniguchi et al., 2002; Werner et al., 2013).	Joost Delsman	07-04-2014
15	2	Deleted	(note that Fig. 7 indicates a continuing increase of SP in the system, this is due, however, to a landward migration of coastal barriers)	Joost Delsman	07-04-2014
15	4	Deleted	however,	Joost Delsman	06-13-2014
15	10	Deleted	The maximum	Joost Delsman	07-04-2014
15	10	Inserted	Maximum infiltration	Joost Delsman	07-04-2014
15	10	Deleted	of about	Joost Delsman	07-04-2014
15	11	Inserted	varied between 20 and	Joost Delsman	07-04-2014
15	11	Inserted	and	Joost Delsman	07-04-2014
15	11	Deleted	, when maximum peat elevations were attained	Joost Delsman	07-04-2014
15	13	Inserted	we	Joost Delsman	07-04-2014
15	13	Deleted	a	Joost Delsman	07-04-2014
15	14	Inserted	low-permeable strata and	Joost Delsman	07-04-2014
15	15	Inserted		Joost Delsman	05-16-2014
15	15	Deleted		Joost Delsman	07-04-2014
15	17	Inserted	Fig. 6e,	Joost Delsman	07-04-2014
15	17	Inserted	gaining	Joost Delsman	07-02-2014
15	19	Inserted	s	Joost Delsman	07-04-2014
15	19	Deleted	since	Joost Delsman	07-04-2014
15	19	Inserted	around	Joost Delsman	07-04-2014
15	19	Deleted	1852	Joost Delsman	07-04-2014
15	19	Inserted	1850	Joost Delsman	07-04-2014

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15	21	Deleted	. Lake reclamation also accelerated the intrusion of sea water, increasing total SP in the system (Fig. 7).	Joost Delsman	07-04-2014
15	22	Inserted		Joost Delsman	07-04-2014
15	22	Deleted	in 1882 AD	Joost Delsman	07-04-2014
15	23	Inserted	eastward and	Joost Delsman	07-04-2014
15	24	Deleted	in 1852 AD	Joost Delsman	07-04-2014
15	25	Inserted	(between x-coordinate 103 and 108 km)	Joost Delsman	05-16-2014
15	26	Inserted	There, groundwater flows upward at a rate of approximately 0.5 m/y, momentarily slowed down between 1900 and 1950 by the overextraction in the dune area.	Joost Delsman	05-16-2014
16	30	Deleted	The chosen model discretization prevents the inclusion of the reported effects of boils (De Louw et al., 2010), highly localized conduits cutting through the low-permeable Holocene strata. The high preferential flow rates associated with boils cause strong local saltwater upconing (De Louw et al., 2013), and explain their significant contribution to the exfiltration of salts in the Haarlemmermeer (Delsman et al., 2013).	Joost Delsman	07-04-2014
16	2	Inserted	The depth and shape of the BGH-type fresh water lens beneath the coastal dunes is not straightforwardly determined by the BGH approximation, but is influenced by both the occurrence of low-permeable sediments below the dunes and groundwater abstraction. Moreover, the fresh water lens is displaced eastward as a result of the steep hydraulic gradient towards the Haarlemmermeer.	Joost Delsman	05-16-2014
16	6	Deleted	Groundwater abstraction in the coastal dunes was at a maximum around 1930 AD and resulted in the salinization and subsequent abandonment of several abstraction wells, clearly visible in both the flow pattern and chloride concentration in Fig. 6j and k.	Joost Delsman	07-04-2014
16	9	Inserted	 Total salt present We calculated the total amount of chloride present in the model (SP), east of the present-day coastline, and the contribution of the different sources of chloride to	Joost Delsman	07-01-2014

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			SP (Figure 8). SP of Transgression origin was the dominant input of chloride (60%), Maassluis origin contributed 24%, while sea water intrusion accounted for 17% of SP. SP predominantly increased before 4500 BC, owing to the infiltration of transgraded sea water.		
16	17	Deleted	therefore	Joost Delsman	07-04-2014
16	17	Deleted	the total amount of salt present (	Joost Delsman	07-04-2014
16	18	Deleted	)	Joost Delsman	07-04-2014
16	18	Deleted	(Fig. 7)	Joost Delsman	07-04-2014
16	18	Inserted		Joost Delsman	07-04-2014
16	18	Deleted	The majority of the i	Joost Delsman	07-04-2014
16	18	Inserted	I	Joost Delsman	07-04-2014
16	19	Deleted	t	Joost Delsman	07-04-2014
16	19	Inserted	T	Joost Delsman	07-04-2014
16	19	Deleted	occurred before	Joost Delsman	07-04-2014
16	19	Inserted	reduced after	Joost Delsman	07-04-2014
16	19	Deleted	as	Joost Delsman	07-04-2014
16	19	Inserted	when	Joost Delsman	07-04-2014
16	20	Deleted	subsequently	Joost Delsman	07-04-2014
16	20	Inserted	Infiltration of transgression water halted completely after the coastal barriers closed around 3300 BC, the continuing increase of SP until 2100 BC is due to a landward migration of coastal barriers. Subsequent infiltration of meteoric water slowly decreased SP until around 1500 AD. Extensive drainage, land reclamation and groundwater abstraction resulted in the reversal of groundwater gradients and promoted the landward migration of sea water intrusion, increasing SP in the groundwater system. The steep increase in SP of Sea origin between 1900 and 1950 was caused by groundwater (over-) abstraction in the coastal dunes. Origin tracers	Joost Delsman	07-04-2014
16	29	Deleted	conservative	Joost Delsman	05-06-2014
16	29	Inserted	origin	Joost Delsman	05-06-2014

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16	29	Inserted	d	Joost Delsman	07-04-2014
16	29	Inserted	comprehensive	Joost Delsman	07-04-2014
16	29	Deleted	n	Joost Delsman	07-04-2014
16	30	Deleted	the origin of	Joost Delsman	07-04-2014
16	30	Inserted	types of different origin	Joost Delsman	07-04-2014
16	31	Deleted	transgression	Joost Delsman	05-16-2014
16	31	Inserted	Transgression	Joost Delsman	05-16-2014
17	6	Deleted	transgression	Joost Delsman	05-16-2014
17	7	Inserted	Transgression	Joost Delsman	05-16-2014
17	11	Deleted	Fig. 8 also demonstrates that infiltrating transgression water is the dominant chloride input to coastal groundwater (57%, Fig. 7), while t	Joost Delsman	07-04-2014
17	12	Inserted	The infiltration of meteoric infiltration water caused the submarine groundwater discharge of earlier transgression water seaward of the coastal dunes (Figure 9d, x coordinate 95 km), owing to a regional seaward flow system underlying the coastal dunes. T	Joost Delsman	07-04-2014
17	16	Inserted	(origin tracer Sea)	Joost Delsman	05-16-2014
17	17	Deleted	is	Joost Delsman	07-04-2014
17	17	Inserted	was	Joost Delsman	07-04-2014
17	17	Deleted	line	Joost Delsman	06-13-2014
17	17	Inserted	general agreement	Joost Delsman	06-13-2014
17	18	Deleted	, and to 13% of the total salt present (SP) in the landward part of the model	Joost Delsman	07-04-2014
17	19	Deleted	constitutes	Joost Delsman	07-04-2014
17	19	Inserted	constituted	Joost Delsman	07-04-2014
17	19	Deleted	a	Joost Delsman	06-19-2014
17	19	Inserted	the	Joost Delsman	06-19-2014
17	19	Deleted	(22%)	Joost Delsman	07-04-2014
17	20	Deleted	predominantly	Joost Delsman	06-13-2014
17	20	Inserted	mainly	Joost Delsman	06-13-2014

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17	20	Inserted	model	Joost Delsman	07-04-2014
17	21	Deleted	The final 8% can predominantly be attributed to dispersion and diffusion of chloride into the remaining fresh water types. This is clearly visible between x-coordinates 105 and 110 km, where the originally fresh recharge from peat areas water type has attained chloride concentrations of over 5 g/L.	Joost Delsman	06-19-2014
18	25	Deleted	Sensitivity runs The performed sensitivity runs did not reveal a significant influence of dispersivity on the general shape of the present-day salinity distribution. Less dispersivity did, however, result in a narrower transition zone between fresh and saline groundwater, most importantly beneath the coastal dunes (100 m to 25 m). Further inland, the width of the transition zone decreased from around 50 m to around 25 m. While measurements indicate a narrow transition zone beneath the coastal dunes, they suggest a wide transition zone further inland and are therefore inconclusive in regards to the “better” value. The Maassluis sensitivity runs revealed a clear dependence of the modeled historical trajectory and present-day location of Maassluis water on its initial chloride concentration. While the general processes acting on this water type remain the same, the extent to which Maassluis water is transported through the subsurface is negatively related to its chloride concentration. At 15 g/L, the density difference between infiltrating transgression water and resident Maassluis water clearly provides less incentive for flow than at 0 g/L. As a result, while a significant fraction of Maassluis water is still present at its original location in the 15 g/L run at model end, it is almost completely displaced in the 0 g/L run, with the 5 g/L and 10 g/L (reference) scenarios in between those extremes. Comparison with the HYFA results of Stuyfzand (1993), although based on only limited samples at the relevant depths, suggests an initial Maassluis concentration of around 10 g/L, showing both the presence of Maassluis at greater depths and a narrow finger of Maassluis around x-coordinate 107 km.	Joost Delsman	07-04-2014

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18	21	Inserted	, and hydraulic parameters of the subsurface	Joost Delsman	05-06-2014
18	21	Inserted	In addition, the employed 2D approach neglects variation perpendicular to the model transect, and the use of time slices introduces discrete and significant jumps in the gradually changing geology and hydrology. Finally, the chosen model discretization prevents the inclusion of boils, highly localized conduits penetrating the low-permeable Holocene strata (De Louw et al., 2010), that contribute significantly to the exfiltration of salts in the polder Haarlemmermeer (Delsman et al., 2013).	Joost Delsman	05-06-2014
18	28	Deleted	perceptual	Joost Delsman	05-02-2014
18	28	Inserted	conceptual	Joost Delsman	05-02-2014
19	22	Inserted	of some meters	Joost Delsman	05-06-2014
19	22	Deleted	fresh water	Joost Delsman	05-06-2014
19	23	Inserted	BGH	Joost Delsman	05-06-2014
19	23	Inserted	vertical	Joost Delsman	05-06-2014
19	23	Inserted	of several tens of meters	Joost Delsman	05-06-2014
19	25	Deleted	fresh water	Joost Delsman	05-06-2014
19	25	Inserted	BGH	Joost Delsman	05-06-2014
19	25	Inserted	, resulting in a transition width controlled by molecular diffusion and pore-scale transversal dispersion (Paster and Dagan, 2007)	Joost Delsman	05-06-2014
19	27	Inserted	. Wide mixing zones associated with vertical seawater intrusion result from the slow mixing of small-scale (meters) seawater fingers with the intermediary fresh water after the fingers reach the aquifer bottom and flow effectively stops (Kooi et al., 2000).	Joost Delsman	05-06-2014
19	30	Deleted	; model	Joost Delsman	05-06-2014
19	30	Inserted	Model	Joost Delsman	05-06-2014
19	31	Inserted	. A dual-domain approach (Lu et al., 2009) could perhaps yield better results	Joost Delsman	05-26-2014
19	32	Deleted		Joost Delsman	06-19-2014
20	17	Inserted	to understand present-day or predict future	Joost Delsman	05-06-2014
20	17	Deleted	of	Joost Delsman	05-06-2014

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20	20	Inserted	, conditioned on present-day boundary conditions	Joost Delsman	05-06-2014
20	21	Deleted	, deriving an initial salinity distribution by a spin-up period with	Joost Delsman	05-06-2014
20	22	Deleted	present-day boundary conditions	Joost Delsman	05-06-2014
20	22	Inserted		Joost Delsman	05-06-2014
20	22	Deleted		Joost Delsman	05-06-2014
21	5	Deleted	perceptual	Joost Delsman	05-06-2014
21	6	Inserted	conceptual	Joost Delsman	05-06-2014
21	27	Inserted	-	Joost Delsman	07-04-2014
21	27	Inserted	We thank two anonymous reviewers whose constructive comments helped improve this paper.	Joost Delsman	08-05-2014
30	1	Deleted	conservative	Joost Delsman	05-06-2014
30	1	Inserted	origin	Joost Delsman	05-06-2014
30	1	Inserted	and relation to hydrosomes.	Joost Delsman	05-06-2014
30	2	Inserted	Related hydrosome	Joost Delsman	05-06-2014
30	3	Inserted	Maassluis (M)	Joost Delsman	05-06-2014
30	11	Inserted	from the surface	Joost Delsman	05-06-2014
30	12	Deleted	from	Joost Delsman	05-06-2014
30	12	Inserted	of	Joost Delsman	05-06-2014
30	11	Inserted	Holocene transgression – Coastal type (LC)	Joost Delsman	05-06-2014
30	15	Inserted	Actual North Sea (S)	Joost Delsman	05-06-2014
30	17	Inserted	Dune (D) west of x-coordinate 105 km, Polder (P) east of 105 km. (Note that the HYFA analysis does not include the area east of x-coordinate 110 km)	Joost Delsman	05-06-2014
30	24	Inserted	Marshlands	Joost Delsman	05-16-2014
30	24	Deleted	peat areas	Joost Delsman	05-06-2014
30	23	Deleted	peat areas	Joost Delsman	05-06-2014
30	24	Inserted	marshlands	Joost Delsman	05-16-2014
31	23	Inserted	Holocene transgression - Ancient Marsh type (Lm1), and Holocene transgression - Young Marsh type (Lm2). The two are differentiated based on the 4 ky age contour obtained by direct age calculations (Goode, 1996) and mixing with	Joost Delsman	05-06-2014

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			Transgression origin.		
31	10	Inserted	Polder (P)	Joost Delsman	05-06-2014
31	11	Inserted	-	Joost Delsman	05-06-2014
32	24	Inserted	.	Joost Delsman	07-04-2014
32	26	Inserted	.	Joost Delsman	07-04-2014
32	28	Inserted	.	Joost Delsman	07-04-2014
34	2	Inserted	Table 3. References for palaeo-model implementation.	Joost Delsman	07-04-2014
37	1	Inserted	/	Joost Delsman	07-04-2014
35	3	Inserted	,	Joost Delsman	07-04-2014
35	3	Deleted	.	Joost Delsman	07-04-2014
35	3	Inserted	dashed line in (b) demarcates Pleistocene and Holocene deposits.	Joost Delsman	07-04-2014
36	5	Inserted	/	Joost Delsman	07-03-2014
36	2	Inserted	(a-f) and sea level rise (g, adapted from (Plassche, (1982)). Red dots and letters in g) refer to corresponding palaeo-geographical map a-f	Joost Delsman	05-02-2014
36	3	Deleted	(	Joost Delsman	05-03-2014
36	3	Deleted	,	Joost Delsman	05-03-2014
37	4	Inserted	For reference, note that the extent of the palaeo-geographical maps equals the extent of Fig. 1a. / Figure 3. Conceptual model representation.	Joost Delsman	05-02-2014
37	5	Inserted	4	Joost Delsman	08-12-2014
37	5	Deleted	3	Joost Delsman	07-04-2014
37	5	Inserted	(Figure 1)	Joost Delsman	07-04-2014
38	8	Inserted		Joost Delsman	05-26-2014

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39	2	Inserted	/	Joost Delsman	05-26-2014
39	3	Inserted	5	Joost Delsman	08-12-2014
39	3	Deleted	4	Joost Delsman	07-04-2014
40	1	Inserted	/	Joost Delsman	07-04-2014
40	2	Inserted	6	Joost Delsman	08-12-2014
40	2	Deleted	5	Joost Delsman	07-04-2014
40	3	Deleted	water types	Joost Delsman	05-06-2014
40	3	Inserted	origin tracers	Joost Delsman	05-06-2014
40	4	Deleted	,	Joost Delsman	05-16-2014
40	5	Deleted	and polder	Joost Delsman	05-16-2014
40	5	Deleted	s	Joost Delsman	05-16-2014
40	7	Deleted	We mapped modeled water types to hydrosomes in b) as follows: M = Maassluis, D = Recharge and Surface water below dune area, LC = Transgression, Lm1 = Recharge peat areas, age > 4 ky, Lm2 = Recharge peat areas, age < 4 ky, P = Surface water, and S = Sea.	Joost Delsman	05-06-2014
40	9	Inserted	See Section 2.3 for a description of discerned hydrosomes, and Table 1 for the mapping of origin tracers to hydrosomes, dots and dashed lines in (a) denote locations of piezometers used in HYFA.	Joost Delsman	05-06-2014
40	13	Deleted		Joost Delsman	05-16-2014
40	13	Inserted		Stuyfzand, Pieter	05-11-2014
41	2	Inserted	/	Joost Delsman	07-09-2014
41	2	Deleted		Joost Delsman	05-26-2014
41	3	Inserted	7	Joost Delsman	08-12-2014
41	3	Deleted	6	Joost Delsman	07-04-2014
41	3	Deleted	k	Joost Delsman	07-04-2014

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41	3	Inserted	g	Joost Delsman	07-04-2014
41	5	Deleted	s show the chloride concentration at the end of a time slice	Joost Delsman	07-04-2014
41	5	Inserted	times correspond to palaeo-geographical maps in Figure 2	Joost Delsman	07-04-2014
42	1	Inserted	/	Joost Delsman	07-04-2014
42	2	Inserted	8	Joost Delsman	08-12-2014
42	2	Deleted	7	Joost Delsman	07-04-2014
42	2	Inserted	and	Joost Delsman	07-04-2014
42	2	Deleted	and the combined other water types	Joost Delsman	07-04-2014
42	3	Deleted	the	Joost Delsman	05-26-2014
43	7	Inserted	 /	Joost Delsman	05-16-2014
43	2	Inserted	9	Joost Delsman	08-12-2014
43	2	Deleted	8	Joost Delsman	07-04-2014
43	2	Inserted	g	Joost Delsman	07-04-2014
43	2	Deleted	k	Joost Delsman	07-04-2014
43	2	Inserted	White lines are contours of the stream function, contour intervals are equal for all time slices.	Joost Delsman	05-16-2014
43	4	Deleted	s	Joost Delsman	07-04-2014
43	4	Deleted	show	Joost Delsman	07-04-2014
43	4	Inserted	times correspond to palaeo-geographical maps in Figure 2	Joost Delsman	07-04-2014
43	4	Deleted	ends of time slices	Joost Delsman	07-04-2014