Citation:

Bruyn, H.E. de, Some considerations on hte conclusions arrived at in the communication made by prof. Eug. Dubois in the meeting of June 27, 1903 entitled: Some facts leading to trace out the motion and the origin of the underground water of our sea-provinces, in:
KNAW, Proceedings, 7, 1904-1905, Amsterdam, 1905, pp. 45-53

the curve then each straight line through P has *zero* points of intersection P with the curve; in other words P is *a point of the order zero* of the curve, so $t' = 0$. So the result of all our considerations is included in equation (3).

We formulate this in the following way:

THEOREM II. *Let P be a point of the order t' of an algebraic curve (where t' may also be zero) and S an arbitrary point of the order t of that curve. Suppose the straight line PS intersects the curve in w points coinciding with S, then the class of the curve is equal to t' increased by the sum of $w—t$ over all the points S of the curve. If S is in P we have to regard all straight lines through P as the line connecting P and S.*

When speaking of *all points S* or, when S is in P, of *all straight lines through P*, we mean that we take those points or lines contributing to $\Sigma (w_1 - t_1)$ and as many other points or lines as one likes.

Theorem I is a special case ($t' = 0$) of this theorem II. The theorem always holds good for any singularities the curve may have.

Sneek, May 1904.

Geology. — "*Some considerations on the conclusions arrived at in the communication made by* Prof. EUG. DUBOIS *in the meeting of June* 27, 1903, *entitled: Some facts leading to trace out the motion and the origin of the underground water of our sea-provinces.*" By H. E. DE BRUYN.

(Communicated in the meeting of September 26, 1903).

In the meeting of June 27, 1903 Prof. DUBOIS made a communication dealing with a problem of great general importance, namely the presence of proper drinking-water in the province of Holland. Although readily acknowledging the many points of merit of this communication and entirely agreeing with many of its conclusions, I differ from the author on a principal point which indeed is essential, namely the origin of the fresh water in our polderland. So a speedy refutation of the author's opinion on this point seemed to me to be desirable.

In his communication Prof. DUBOIS speaks of our sea-provinces; this in my opinion ought to be Holland, since the conditions prevailing in Friesland and Zeeland are different, so that considerations which are valid for Holland cannot be applied there. So I will only consider the tract of country chiefly dealt with in the above-mentioned communication, which is bounded by the dykes of the Y and the Zuiderzee at the north, by the river Vecht at the east, the Rhine from Harmelen to Katwijk at the south and the North-sea at the west.

The geological conditions of this tract inside the dunes are such as are mentioned in the communication: uppermost alluvium, then pretty generally a layer of fen (partly disappeared) under which a layer known as "old sea-clay". Under this latter the diluvium, consisting to a great depth of sand, coarser and finer, with here and there banks of clay which are not continuous however. The "old sea-clay" mentioned is called in the paper clay-containing sand and although in my opinion also that layer is permeable to water, yet I think its permeability is smaller than Mr. DUBOIS assumes and that it is exactly here that the cause of our difference of opinion has to be sought. In some places this layer of old sea-clay is wanting, in special cases this makes an investigation very difficult, for the general condition however, which is here dealt with, this circumstance can be neglected.

The communication consists chiefly of two parts, of facts and of conclusions drawn therefrom. The facts I will pass without commenting on them, although occasionally objections might be raised against them or rather against the remarks that accompany them.

I perfectly agree with a great many of the conclusions, e.g. with the following:

that in the diluvium fresh water is present to a certain depth;

that in deeper polders the deep groundwater moves vertically upward, in shallow polders downward;

that also in the depth a current exists from the dunes to the polders and from the shallower polders to the deeper ones;

that no important continuous subterranean current exists from the higher grounds from the east to the west.

But I cannot accept the conclusion that the fresh groundwater present in the diluvium also in our polders, owes its origin to rain fallen locally or at a relatively short distance during the wet season.

In the following refutation of this opinion I shall speak of fresh and of brackish or salt water. Of course there is no sharp division between these, but in order to avoid cumbrous definitions I shall make this distinction for simplicity's sake. I base my considerations on quantities, but since only their relative amount concerns us here, I have rounded my figures as much as possible.

I intend to show the incorrectness of the conclusion mentioned from the amount of the afflux to in the Haarlemmermeer polder. Now a paper on this amount by the member of this Academy

VAN DIESEN is found in the Versl. en Meded. der Kon. Akad. 1885[1]). I can by no means accept the amount found there. The chief reason why Mr. VAN DIESEN arrived at an erroneous figure is that he assumes that the groundwater in the Haarlemmermeer polder which is situated at a depth of about a metre below the surface evaporates as much as water at the surface on account of the interstices between the particles of ground. This, I think, is entirely wrong; groundwater at a depth of a metre does not evaporate at all.

Now if we assume that the groundwater does not evaporate, the figures given in the paper would lead to a negative afflux, which certainly is wrong too. This is a consequence of another reason why an erroneous figure is found, namely the method of derivation. Mr. VAN DIESEN, namely, calculates the amount of the afflux from two periods of six years, for each of which he derives the equation·

$$k = ax - b$$

in which k is the amount of the flow, x the ratio of the evaporation at the surface and the rain fallen; a and b constants, derived from the other data. So he has two equations $k = ax - b$ and $k_1 = a_1x_1 - b_1$. Now he determines the ratio of k and k_1 from the difference in level of the water in the "bosom"[2]) and of the polderwater, a ratio naturally little differing from unity, he further assumes that the x of each period has the same average value, so he puts $x = x_1$. The two unknown quantities, k and x, can then be found from these two equations.

But x and x_1 are not exactly equal. Mr. VAN DIESEN himself says: "evidently this value must change according to circumstances." If x_1 be equal to $x + \Delta$ we have·

$$x = \frac{\frac{k}{k_1}b_1 - b}{\frac{k}{k_1}a_1 - a} - \frac{\frac{k}{k_1}a_1\,\Delta}{\frac{k}{k_1}a_1 - a}$$

Now it will entirely depend on the value of $\frac{k}{k_1}a_1$ and a whether Δ has an appreciable influence on the value of x. Since from the nature of the case $\frac{k}{k_1}a_1$ and a are great values, differing little between each other, however, a small value of Δ has a great influence on x and hence on k.

[1]) Versl. en Meded. van de Kon. Akademie van Wetenschappen, Afd. Natuurk. 3e Reeks, Dl. I, p. 359—374.

[2]) "Bosom" is called an intermediate discharge canal or basin.

The best estimate of the afflux in the Haarlemmermeer polder is that by Mr. ELINK STERK [1]). This author bases his calculation on the assumption that the value of rain minus evaporation, averaged over many years, is practically the same for Rijnland and for the Haarlemmermeer polder. Rain is here tacitly assumed to be rain plus surface condensation, and evaporation, evaporation plus the water withdrawn by plants. From the quantity of water discharged and let in over an average of 14 years Mr. ELINK STERK then derives with the aid of the assumption mentioned that the afflux in the Haarlemmermeer polder is equal to a quantity of water corresponding to a height of 135 mm. $+ K$ (K being the afflux in Rijnland) over the whole surface.

Now he puts $K = 15$ mm. i.e. $^1/_{10}$ of the afflux in the Haarlemmermeer polder which he calls an ample estimate as I think it is; so he finds for the amount of the afflux in the Haarlemmermeer polder 150 mm.

The assumption mentioned that rain minus evaporation is equal for Rijnland and for the Haarlemmermeer polder is not quite correct of course. The rain may be taken equal, but not the evaporation. The rainfall is in my opinion more regular on the average than is indicated by our rain-gauges. Under equal meteorological conditions the rate of evaporation depends principally on water for evaporation being or not being present. In the polders having a high summer-level with regard to the land which mostly consists of meadows, evaporation will be greater than in the Haarlemmermeer polder, since water will always be present at the surface; in the dunes on the other hand it will be less. Considering the character of the grounds in Rijnland we may assume that evaporation there will be slightly greater than in the Haarlemmermeer polder. So if we apply to our figure a correction Δ_1, making it $150 + \Delta_1$, Δ_1 will be negative.

Mr. ELINK STERK has left out of consideration through lack of data: 1. the quantity of water admitted into the Groot Waterschap van Woerden (having the same bosom as Rijnland); 2. The quantity of water let in by locks into Rijnland and the Groot Waterschap van Woerden. Calling these respectively Δ_2 and Δ_3, the afflux in the Haarlemmermeer polder is

$$k = 150 + \Delta_1 + \Delta_2 + \Delta_3 \text{ mm.}$$

Now the quantities Δ_2 and Δ_3, are both small and certainly positive; probably they are together smaller than Δ_1. So if we omit the three corrections Δ_1, Δ_2 and Δ_3, the error can not be large and

[1]) Verhandelingen van het Kon. Instituut van Ingenieurs. 1897—1898. p. 63—75.

the figure for k probably becomes too great as it also becomes by putting $K = 15$ mm.

Putting the afflux of water at 150 mm. this gives for a surface of 18000 H. A. 27 million M^3. This amount consists of three parts: 1. of what is let in for the higher lands behind the ringdyke through valves and syphons; 2. of the afflux through the ringdyke above the old sea-clay which I shall call the afflux *through* the alluvium; 3. of the afflux over the whole surface of the polder, moving upward through the old sea-clay on account of the greater pressure, which I shall call the afflux *from* the diluvium.

The first part which is no proper affluw, is estimated by Mr. ELINK STERK at 5 to 7 million M^3 per year. Subtracting this and taking the smallest figure the afflux mentioned sub 2 and 3 becomes 22 million M^3 per year. How much of this is due to each of the parts sub 2 and 3 cannot be made out, while in those places where the "old sea-clay" is absent no separation takes place. Probably 2 is the greater part, therefore I assume for the part sub 3 an amount of 10 million M^3 per year; possibly it is much smaller.

These 10 million M^3. the afflux *from* the diluvium must consequently either flow in as fresh water along the circumference of the polder under the old sea-clay through the upper layers of the diluvium, or rise from below as salt water. Let us for the present assume that it all flows to in the former manner. In fifty years 500 million M^3. of fresh water would in this way have flowed into the diluvium. Now the quantity of fresh water present in the diluvium under the Haarlemmermeer polder is *greater*; assuming $^1/_3$ to $^1/_4$ space between the grains of sand this quantity would only correspond to a thickness of 10 metres containing fresh water, whereas this thickness is greater on the average, as is proved e.g. by borings near Sloten.

The circumference of the ringdyke being about 60.000 metres, if we assume the afflux to take place over a height of only 20 metres and the interstices between the grains of sand to be the same as above, this will give a velocity of motion of 30 metres per year and the water flowed to would, even if we neglect the loss of speed further in the polder, have penetrated into the polder only 1500 metres in 50 years and so not have reached the middle.

Moreover the assumption that all the water streaming to is fresh, is not probable, if we bear in mind the amount of salt in the Wilhelmina spring which is over 3000 mg. chlorine per litre. Hence it is certain that with a flow of 10 million M^3 *from* the diluvium, part of the fresh water nowadays present in the diluvium under the

Haarlemmermeer polder was present there already 50 years ago.

Before that time conditions were very different from what they are now. Instead of the deep drainage there was bosomwater. How the fresh water then present, especially in the eastern part, had come under the Haarlemmermeer, is difficult to tell for want of data. Was the water of the Haarlem lake always so rich in chlorine as some old observations show? Certainly the difference in pressure of the deep groundwater was smaller than it is now and accordingly the quantity of water moved was also smaller, while the direction of the current in the deep groundwater e.g. near Sloten must have been exactly the reverse.

A thousand years ago when there were no dykes yet to keep out the water of rivers and of the sea, and no mills yet to drain the polders, when the dunes were so much broader at the seaside than they are now, when there were no canals in the dunes yet for sand transport and other purposes, I imagine the state of affairs in the tract of land we are considering, must have been such that fresh water was also present in the diluvium and probably more than nowadays, that in the dunes there existed a high level of groundwater by which water was driven to the diluvium, the pressure at the west side under the "old sea-clay" being greater than that of the groundwater above it. The level of the groundwater in the alluvium of the polderland was then probably much more regular and slightly higher than the average sea-level. How these conditions became prevalent I must leave to geologists to explain.

By making dykes, by enclosing polders, by draining, the level of the groundwater has gradually been lowered, now in one place, then in another. The currents in the layers of fresh water in the diluvium also had their directions changed by this; they certainly were very small, however, before the great drainages were made. In the tract we are dealing with, 3000 H.A. were drained before 1750, 10.000 H.A. between 1750 and 1850 and 26.000 H.A. between 1850 and 1900.

The dunes gradually decreased in breadth, while also the flow of water towards the land increased by canals for sand-transport etc. The height of the groundwater in the dunes will consequently also have steadily been decreasing.

Bearing in mind the figure for the amount afflux to in the Haarlemmermeer polder, we may safely assume the quantities of water which before the drainages were made, penetrated vertically downward through the old sea-clay, to have been very small compared with the amount of fresh water present. Consequently the only source of supply of fresh water to the diluvium has been the afflux from the dunes. At the same time I venture the supposition that part of the fresh water which a thousand years ago was present in the diluvium under the polderland is still present there now.

Another question arising here is whether salt water rises upward from below. About former times nothing can be stated with certainty in this respect; for the present time it is rendered probable by the circumstance that the water of the Haarlemmermeer polder contains more chlorine than can be derived from the afflux if no salt water from below is added to it. Therefore I have tried to estimate, though roughly, the quantity of chlorine, discharged by Rijnland and the quantities entering Rijnland in another way than from below, assuming that the quantity of chlorine withdrawn from the ground by plants is equal to the quantity furnished by manuring, which supposition is reasonable.

Rijnland discharges annually on the average 476 million M^3. of water; how much chlorine this contains is not known, but from the data for the percentage of chlorine of the water of the bosom [1]) a figure may be derived which is too small and another which is too large, which figures I take to be 105 and 315 mg. per litre, giving an annual discharge of 50.000 or 150.000 tons of chlorine.

The quantities of chlorine arriving into Rijnland are, besides that from the groundwater below 1. the sea-spray; assuming that this chiefly falls on the dunes we can estimate it; the dunes that discharge water into Rijnland will supply about 20 million M^3. of water annually; this water contains 40 mg. chlorine per litre, making 800 tons of chlorine; adding to this what is blown over the dunes we obtain a total of 1500 tons; 2. the fresh water which is let in, amounting on the average to 125 million M^3. per year, containing 40 mg. per litre, which makes 5000 tons; 3. the water through locks; it is difficult to estimate an average percentage of chlorine here, since one lock (Gouda) admits fresh water to the bosom, others (Spaarndam, Overtoom, etc.) water with a high percentage of chlorine; I think 2000 mg. per litre a sufficiently high estimate; putting the water let in through locks at 5 million M^3. this makes 10.000 tons; 4. what human society discharges into the bosom; this amount is difficult to estimate; putting it at 3500 tons, the total amount becomes

[1]) Mededeelingen omtrent de Geologie van Nederland, no. 26, by Dr. J. Lorié, pp. 8—11.

20.000 tons of chlorine. Assuming that what is supplied to the bosom by all these causes is more than half this rough estimate and less than its twofold we get 10.000 or 40.000 tons of chlorine. In any case there is a deficiency amounting to something between 10.000 and 140.000 tons which has to be ascribed to a supply of salt from a greater depth. When we bear in mind that this will chiefly come from the Haarlemmermeer polder and that this latter discharges on the average about 30.000 tons of chlorine and that the supplies mentioned sub 1—4 occur there in a small degree, the supply of salt from below at the present time is pretty certain. A quantity of 35.000 tons of chlorine corresponds to that contained in two million M^3. of water from the North Sea.

The motion of the deep groundwater is generally very slow.

If e. g. we consider how long it would take water to travel in a layer of sand between two impervious layers from the sea to the Haarlemmermeer polder, which is a distance of 9000 metres, the difference of pressure being 5 M., if the permeability is the same as that of dune-sand, we find that it would travel in a year (31.557.000 seconds) through a distance of

$$\frac{31.557.000 \times 5 \times 0.0006}{9000} = 10 \; M.$$

(0.0006 being the rate of filtration through 1 M. of dune-sand with a pressure of 1 M. [1]). A distance of 9000 M. would consequently require 900 years.

As to the rate with which the salt water can rise from below we find what follows. Assuming that the rise is constant and that under the Haarlemmermerer polder 5 million M^3. rises annually, this gives over a surface of 18000 H.A. with a space of $^1/_3$ to $^1/_4$ between the grains of sand, a rise of about 100 mm. per year; a rise of 50 metres would then require a period of 500 years.

The question now naturally arises: since a large quantity of fresh water is present in the diluvium under our polderland and the salt water flows slowly, is it possible to withdraw this fresh water for drinking-water? The part we are considering has, after taking off the littoral margin and the country round Amsterdam which has a different formation, a surface of about 100.000 H.A.; not counting the drainages and other less suitable tracts, half of this territory contains 5000 million M^3. of fresh water, if we assume an average

1) Report of the Committee for investigating the supply of water from the dunes to Amsterdam, 1891, supplement 16, p. 77.

of 10 M^3 of fresh water per M^2, corresponding to $^1/_3$ to $^1/_4$ space between the grains of sand over a thickness of 30 to 40 metres. A consumption of 50 million M^3 per year being sufficient with the existing dune-water conduit for the need of the population, taking its increase into account, this quantity would be able to supply water for a hundred years; now we may presume that in a hundred years science will have so much advanced that it will be practicable then to convert any water into suitable drinking-water.

The answer to our question must in my opinion be affirmative as well as negative. Affirmative with respect to supplying water to single dwellings, to a village, or to a temporary supply in war-time such as the Engineering Corps has made at Sloten; negative with respect to a lasting demand on a large scale and this because in practice pecuniary considerations would force us to withdraw the water from a limited surface which would be impossible without causing such a diminution in pressure that certainly with a lateral afflux also water from below would flow to, so that after some time brackish water would be obtained.

Hence Prof. DUBOIS' assertion, that a sufficient quantity of drinking-water is and remains available in the ground under the shallower polders, is in my opinion entirely wrong.

Geology. — *"On the origin of the fresh-water in the subsoil of a few shallow polders"*. By Prof. EUG. DUBOIS. Communicated by Prof. BAKHUIS ROOZEBOOM.

(Communicated in the Meeting of November 28, 1903).

In the meeting of the Academy of September 26 ult. Mr. H. E. DE BRUYN, although he agreed with most of the principal conclusions about the origin and the direction of motion of the groundwater in part of our lowland, contained in my communication to the Academy of June 27, gave an elaborate exposition of the grounds on account of which he cannot accept my conclusion concerning the origin of the fresh-water in the subsoil of a few shallow polders. In my opinion this has to be sought in rain, fallen on the spot or at a relatively short distance, which Mr. DE BRUYN thinks impossible on account of considerations about the amount of the afflux in the Haarlemmermeer polder which, in his opinion proves that the layers above the diluvium, especially the "old sea-clay" transmit water to a much smaller extent than is necessary in my representation. He also supposes that part of the fresh-water which was present under our polder-land a thou-