DELIMITATION OF THE PERIMETERS OF PROTECTION OF THE WELLFIELD IN THE CITY OF ADRAR, SAHARA OF ALGERIA THROUGH THE USED WYSSLING'S METHOD AND GIS

[1]AHMED FILLALI, [2]DJAMEL AMRANE

[1]Hydrogeology Engineer Foggara Observatory, Integrated Water Resource Management Agency Algeria [2]Baichi Said Technical Engineering Office in Hydraulics, Algeria
E-mail: [1]fillaliahmed@hotmail.com, [2]djamelamrane0119@gmail.com

Abstract - The delimitation of the perimeters of protection in the catchment area of the city of Adrar, which are established around the sites for the collection of water intended for human consumption of drinking water, with the objective of ensuring the preservation and reducing the risks of point and accidental pollution of the resource (Continental Intercalar groundwater of the Northern Sahara of Algeria). This wellfield is located in the northeast of the city of Adrar, it covers an area of 132.56 km2 with 21 Drinking Water Supply wells (DWS), pumping a total flow of approximate 13 Hm3/year. The choice of this wellfield is based on the favorable hydrodynamic characteristics and their location in relation to the agglomeration. The vulnerability to pollution of this slick is very high because the slick is free and suffers from the absence of a protective layer. In recent years, several factors have been introduced around the field that can affect the quality of this precious resource, presence of a strong centre for domestic waste, agricultural and industrial activities. Thus, its sustainability requires the implementation of protection perimetere. The objective of this study is to set up three protection perimeters: immediate, close and remote. The application of the Wyssling method makes it possible to calculate the transfer time (t) of a drop of groundwater located at any point in the aquifer up to the abstraction and thus to define isochrones which in turn delimit each type of perimeter, 40 days for the nearer and 100 days for the farther away. Special restrictions are imposed for all activities depending on the distance of the catchment. The application of this method to the Adrar city catchment field showed that the close and remote protection perimeters successively occupy areas of 51.14 km2 and 92.9 km2. Perimeters are delimited by geolocated markers, 40 and 46 markers successively. These results show that the areas defined as "near protection perimeter" are free from activities likely to present a risk to the quality of the water used. On the other hand, on the areas defined as "remote protection perimeter" there is some agricultural and industrial activities that may present an imminent risk. A rigorous control of these activities and the restriction of the type of products applied industrial and agricultural is imperative.

Keywords - Continental Intercalaire, Drinking Water Supply, Groundwater, Perimeter of protection, Wyssling Method.

I. INTRODUCTION

At the level of the city of Adrar, groundwater accounts for about the entire quantity of water mobilized for drinking water supply. (Guo et al., 2008) They generally offer the advantage that they do not require extensive treatment before being made available for distribution. The perpetuation of this resource requires the creation of protective perimeters to avoid various types of pollution that can alter the quality of the water table. The quantity and quality of groundwater resources have been increasingly degraded in recent years as a result of population development (Zhang et al., 2020), and economic activities and the presence of pollution sources caused by anthropogenic activities have increased the demand for water (Chaudhary and Walker, 2019), this situation has accentuated the downward trend in the level of the water table in the city of Adrar, which has sometimes become critical. As a result, it has become necessary to put in place mechanisms and actions aimed at the preservation and safeguarding of these resources.

Local contamination prevention includes the establishment of protective perimeters around boreholes. It is now necessary to undertake protection actions for the different perimeters of the catchment area of the city of Adrar, (Merah et al., 2019) which is the objective of this phase of the study, entitled: "Delimitation of protection perimeters" (Jiménez-Madrid et al., 2019).

II. MATERIALS AND PROCEDURES

2.1. Hydrodynamic characteristics of the catchment field of the city of Adrar

To this end, we organized a field visit with the aim of making an inventory of the DWS boreholes in the catchment field of the city of Adrar, in collaboration with the engineers of Water Algeria (ADE). Parameters of top coat parameter are given in Each well has been examined on the basis of a technical data sheet, with the following superscript: Waterproofing Fences, Environment.

2.2. Hydrodynamic characteristics of the hydrodynamic field capturing the city of Adrar

The catchment area of the city of Adrar, is part of the Continental Intercalary (CI) aquifer, which outcrops widely in our study area.

Basic characteristics of the CI for the supply area of the common city of Adrar:

Water point: 21 water points (Argus and Matthews)
Average depth: 100 to 150 m
Operating flow rate (l/s): 25 to 50

Lithology: Sand, sandstone and clay.
Agglomerations supplied: the city of Adrar, the agglomeration of the commune of Bouda and Timmi.

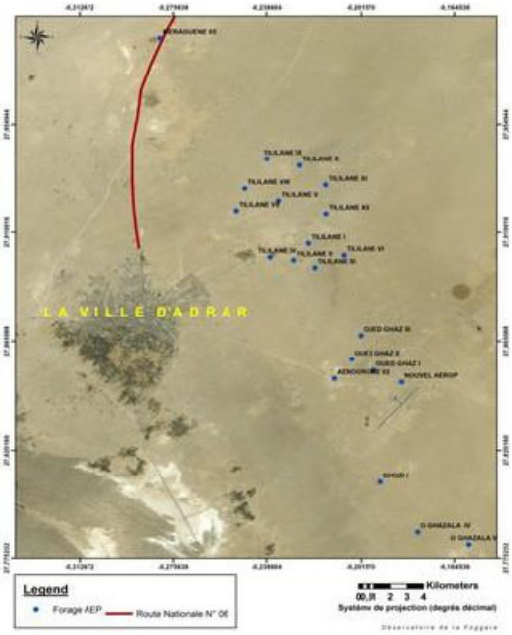

Fig. 01: Location map of DWS wells (on Google Earth)

III. RESULTS AND DISCUSSION

3.1. Exploitation of the Groundwater:

According to the ADE's inventory of water points, the well bore flows vary between 25 and 30 l/s, but they can be as high as 50 l/s. In 2016, the total flow withdrawn from the reservoir is estimated at 11445472 m3/year, whereas in 2011 it was m3/year. The flow withdrawn from the aquifer is doubled due to the extension of the city of Adrar. This increase in flow has resulted in the completion of numerous boreholes.

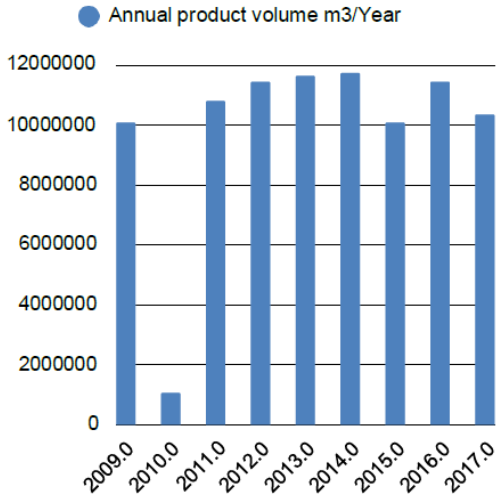

Fig. 01: Monthly levy (2009-2017)

3.1.1. Piezometry and horizontal capture field transfer mode

The processing of the 2009 ANRH piezometric data using Surfer and Arc-Gis software helped us to draw the piezometric map of the catchment field of the city of Adrar (figure 06). The latter shows that the piezometric shows a decrease of about 245 m towards the North-West.

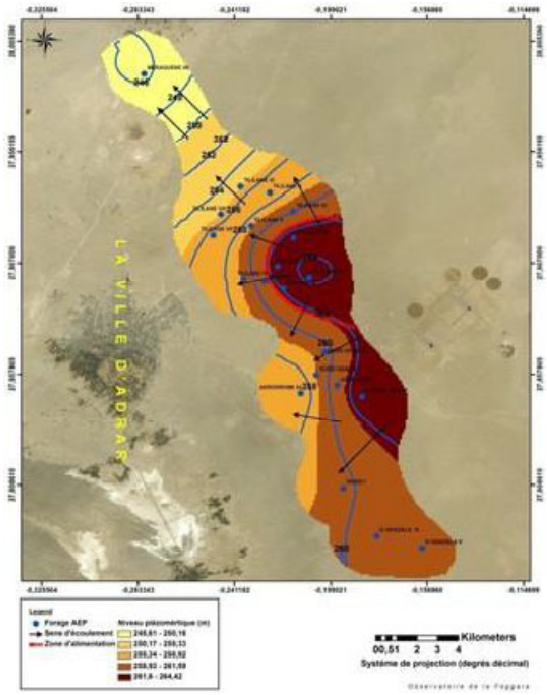

Fig. 02: Piezometer map of the catchment field

As a result, the flow is from southeast to northwest. The 21 wells in the Adrar catchment field are located between the two piezometric levels 245m and 255m.But with a significant drawdown in the order of 20 to 50 cm around the catchment area of the city of Adrar.

3.1.2. Transmissivity T

Analysis of the different results of the pumping tests carried out in the study area using Aquitest software to interpret these results shows that there is not much variation in the values of slick transmissivity (), as there is not a large lateral change in facies and the slick is free throughout the study area (). The analysis of the different results of the pumping tests carried out in the study area, using Aquitest software to interpret these results, shows that there is not a large variation in the values of slick transmissivity, given that there is not a large lateral change in facies and that the slick is free throughout the study area.The transmissivity map drawn up from the data from the pumping tests (Figure 08) shows that the transmissivity values in the area where () the Continental Interlayer outcrops are of the order of 0.04 m2/s. The areas of hight transmissivity are

generally located in the North-East of the city of Adrar. The areas of low transmissivity are generally located to the east of the city of Adrar, due to the reduction in the thickness of the Continental Intercalaire.

3.1.3. Storage Coefficient E

We used the ANRH data using the Aquitest pumping test interpretation to map the storage coefficient. The reconstitution of the storage coefficient map (figure 08) shows that the values of the coefficient are of the order of 0.002 at the catchment field of the city of Adrar.

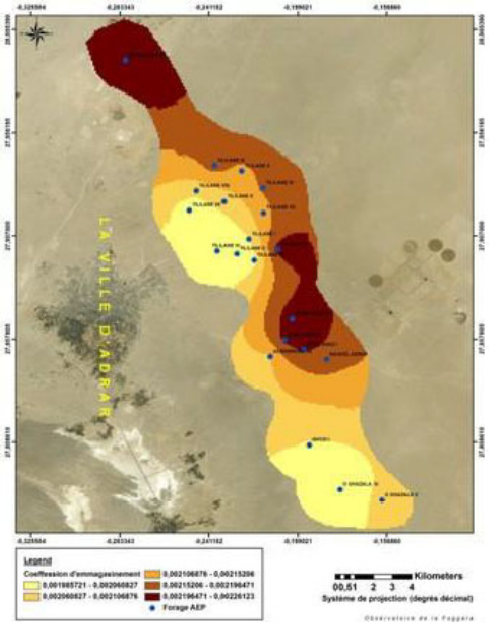

Fig. 03: Map of storage coefficient E

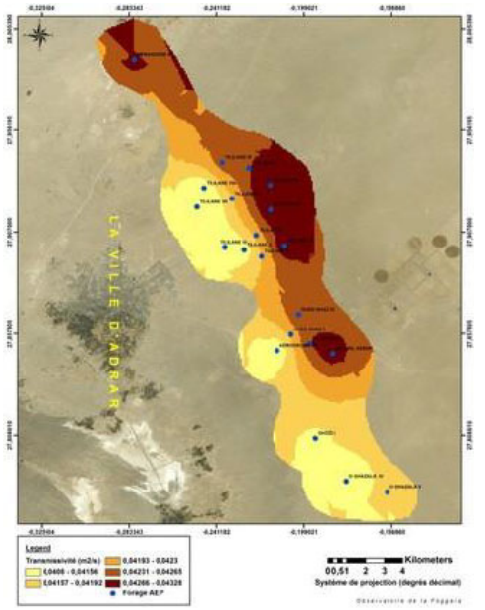

Fig. 04: Transmissivity card T

3.2. Wyssling's Method :

The Wyssling method makes it possible to calculate the flow time (t) of a drop of groundwater located at any point in the aquifer up to the catchment and thus delimit the isochrones necessary for the definition of protection perimeters ().

It is based on the basic assumption that conditions in the aquifer are more or less homogeneous and that the abstracted flow
(Q) is significantly lower than the total groundwater flow.

For isochron calculations by Wyssling's method, it is necessary to know:

- The direction and the flow gradient;
- The geometry of the aquifer (its thickness at the point of capture);
- The permeability of the aquifer;
- The effective porosity of the aquifer; In free sheet, we can consider that S is of the equivalent).
- The average exploitation rate for wells.

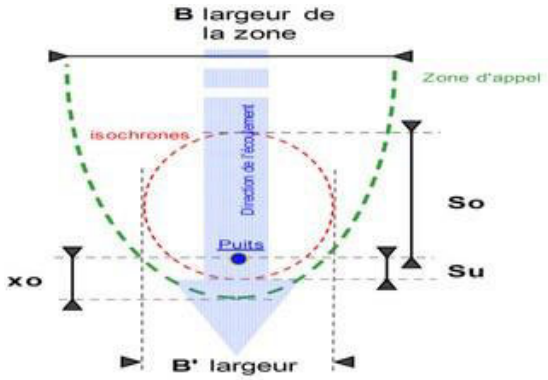

Fig 05: Determination of isochrones (Wyssling method)

An application has been developed in Excel to calculate the 50 and 100-day isochrones according to the Wyssling method. This application is based on the Wyssling formula; the dimensions of the isochrones can be calculated by simply entering the various parameters of the formula relating to the well () ().

3.2.1 The Direction and Gradient of Flow

The direction of flow is calculated for each well, based on the piezometric map developed by the field data in 2014. This results in flow direction angles. This piezometric map was also used to calculate the hydraulic gradient for all the EAF boreholes in the wellfield.

3.2.2 The thickness and Conductivity Hydraulic of the aquifer

The Conductivity Hydraulic values are taken from a long-term pumping test which will give the Transmissive (T), the product of permeability and wet thickness ().

In the absence of permeability data (K), it was possible to replace them with standard values, depending on the geological sections available (80 sections). For the remaining boreholes that do not have geological sections, the permeability values are extracted by the triangulation method on the basis of the 08 existing wells.

3.2.3 The effective porosity of the aquifer

In our study area, storage coefficient E can be considered to be of the same order of magnitude as the effective porosity).In the absence of data, it was possible to replace them with standard values.(Fig. 03).

3.2.4 Average exploitation flows for wells:

The results obtained from the various calculated data were used to develop the Wyssling method protection perimeters for a transfer time of 50 and 100 days, in order to determine the 50 and 100-day isochrones that correspond to the close and distant protection perimeters.



Fig. 06:Conductivity Hydraulic

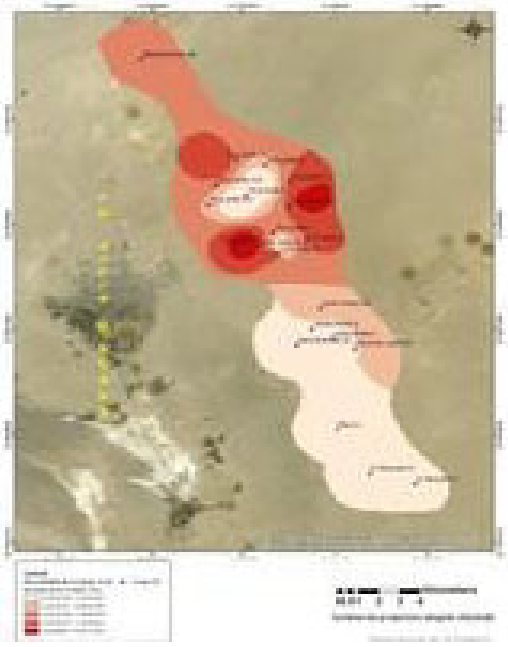

Fig 07:Hydraulic gradient

3.3 Delimitation Protection Perimeter

3.3.1 Immediate Protection Perimeter (IPP)

The immediate perimeter of protection (or immediate perimeter) is a restricted space intended for the protection of the work itself, in which all activities are prohibited, with the exception of water exploitation.

The functions of the immediate protection perimeter are therefore to prevent deterioration of the sampling structures and to prevent spills or seepage of polluting substances from occurring within or in the immediate vicinity of the catchment.

3.3.2 Close Protection Perimeter mapping (PPR)

It is established on the basis of the catchment area created by the structure, or by the definition of a transfer isochron.

The extent of this perimeter is defined in such a way as to ensure a transfer time of potentially polluting substances to the catchment that is long enough to allow intervention if necessary.

In order to determine the 50-day isochron, the application of Wyssling's method allows us to calculate the ellipsoid for each well; it consists of grouping the ellipsoids in a protective perimeter.

The close protection zone is determined by taking into account in particular:

- The physical characteristics of the aquifer and groundwater flow
- The maximum pumping rate
- Vulnerability

Table: Calculated parameters for boreholes and 50-day isochrones.

The area is divided into five (05) perimeters that are near each other due to the remoteness of the water points.

3.3.3 Remote protection perimeter mapping (PPE)

The remote protection perimeter (or far perimeter), which surrounds the near protection perimeter, is intended to allow space management in which land use planning and water protection coexist. The remote protection, perimeter has a larger area, corresponding to the catchment area. Due to the local context, it is impossible to take into account the local geological and hydrogeological context.

The delineation of protection perimeters away from the wellfield wells is determined by calculating the 100-day isochrones using the Wyssling method.

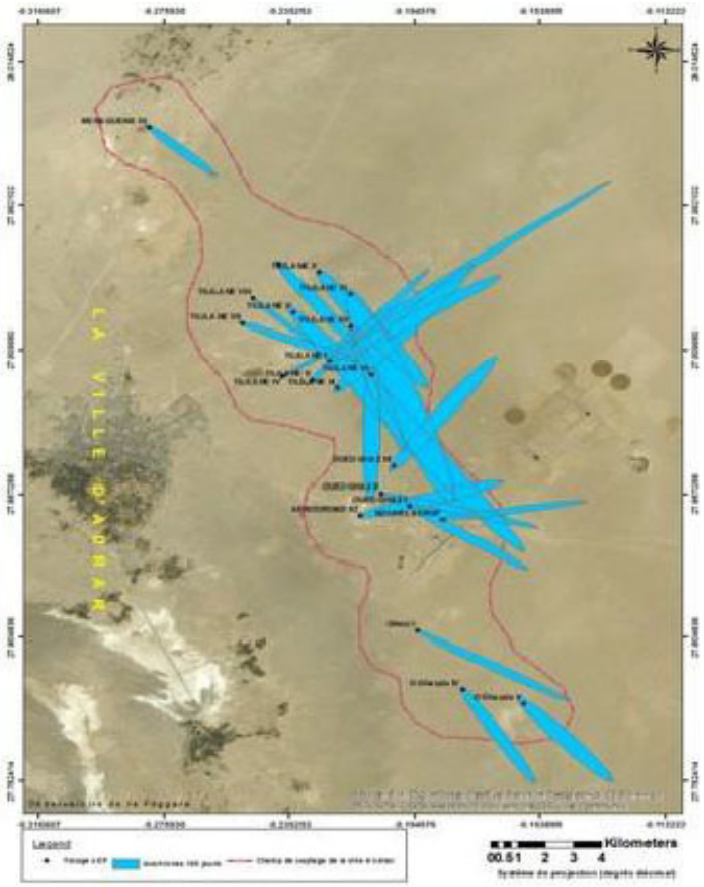

Fig 08 : Map of the 100-day isochrones around the wells in the catchment field of the city of Adrar

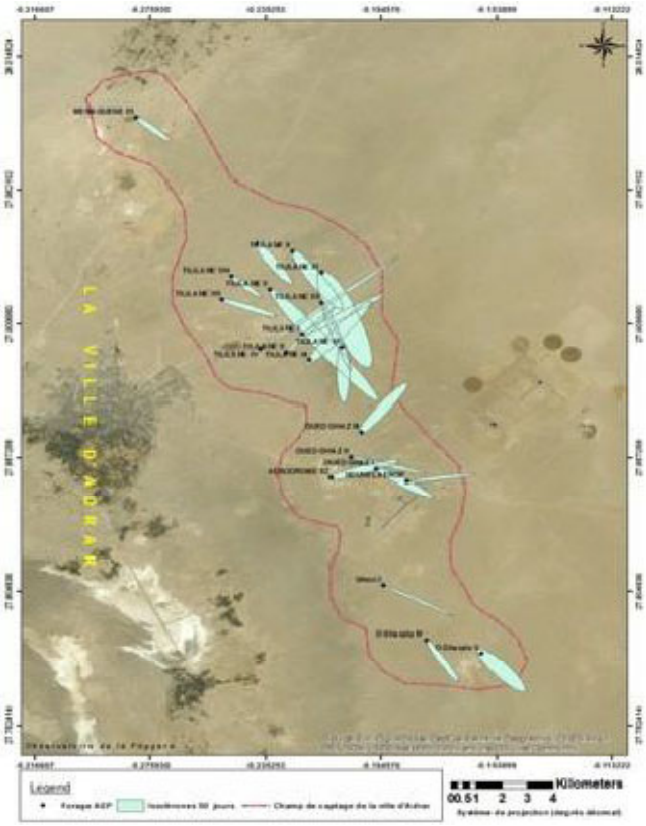

Fig 09 : Map of the 50-day isochrones around the wells in the catchment field of the city of Adrar

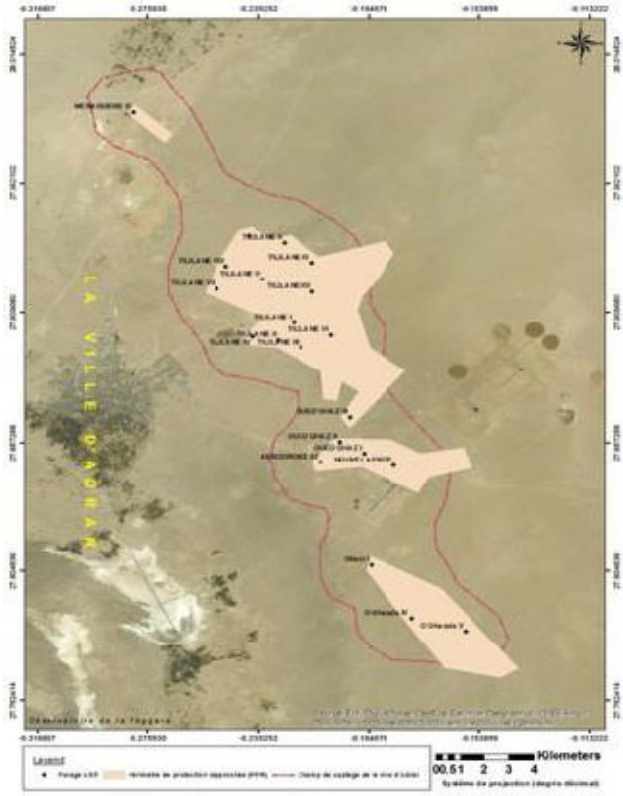

Fig 10 : Map of the Remote Protection Perimeter of the catchment area



Fig 11 : Map of the Close Protection Perimeter of the catchment area

IV. CONLUSION

The application of these three protection perimeters will guarantee good conservation of these underground resources which are becoming increasingly rare. The potential sources of pollution that can degrade water quality are agricultural and industrial pollution and urbanization.

Moreover, the exploitation of this water table by industrialists and farmers can have a non-negligible impact on the drinking water supply.

Because of its fragility, it would be advisable to carry out special monitoring of this slick; it is therefore necessary to regularly monitor the boreholes located within the wellfield. The establishment of the three protection perimeters around the water points intended for the PEA is highly recommended

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