RESEPONSE TO REFEREE 1:

I would like to thank you for your comments. I feel that the modifications made to the paper have truly contributed to its improvement. In order to take account of your comments, the following changes (which appear in red in the manuscript) have been made to the paper:

General comments

I find this article of little scientific significance. The article manuscript does not represent a substantial contribution to scientific progress within the scope of Hydrology and Earth System Sciences. It does not present any substantial new concepts, ideas or methods. If anything, it presents very site-specific information on a case of overexploitation of a local aquifer (or group of aquifers) in Spain.

With all respect and humility, I consider that the article does provide an interesting contribution to the field of aquifer exploitation on an international stage because, in addition to highlighting the many and exaggerated negative effects that this phenomena has caused in south-eastern Spain (result of the author's research over more than 40 years), the paper deals with the Ascoy-Sopalmo aquifer, which is not just any Spanish aquifer of local interest, but the most-seriously overexploited aquifer in Spain and probably Europe (with pumped abstractions 27 times greater than its resources). The most alarming consequence of overextraction has been its separation into parts - since the maximum degeneration that an aquifer can suffer is to lose its own integrity (devolving from a single unit into several). As far as the author knows, such a phenomenon has not been described in the hydrogeological literature elsewhere, but only in Spain. In this respect, the author was the first to speak about compartmentalization in a Spanish aquifer - the Quibas aquifer - in 1979, in a Spanish journal (Rodríguez -Estrella, T.: Contribución de la Hidrogeología al conocimiento tectónico en el Sureste Español. *II Simp. de Hidrog*. 359-380. Pamplona. 1979). For these reasons, I sincerely believe that the Hydrology and Earth System Sciences journal is the ideal forum for presenting this unique case study of compartmentalization in the Acoy-Sopalmo aquifer at international level.

Specific comments

*In chapter **2.1** the author presents a very brief semantic review of the word "overexploitation", neglecting at the end to state which meaning of the term he is adopting in the chapter **3 Effects of aquifer overexploitation** of his article. Yet, the caption of chapter* **3 Effects of aquifer overexploitation** *notwithstanding*, *the discussion of the chapter is entirely on a rather nebulous term "**intensive exploitation". ***While "**intensive exploitation"** can be either sustainable or unsustainable (hence its ambiguity), I believe that the term "aquifer overexploitation" is unambiguously synonymous with "unsustainable production of ground-water".*

In my opinion, I think that the concept that the author promotes about overexploitation can be found in the article (*i.e.*, unsustainable exploitation), since the text even provides a definition, based on that of Pulido (2001), written in italic script. Nevertheless, if there were any doubt, the text now outlines the reasons why the author inclines towards the use of the term "overexploitation" and not "intensive exploitation":

"Over the last twenty years, some authors have been completely against using the term "overexploitation" because of its implied negative connotation, and propose instead the term "intensive use" (Custodio 1989).

The author disagrees with this term, since the word "intensive", according to the *Oxford English Dictionary*, means "more intensive, energetic or active" but does not imply "exceed, go above", as does the term "overexploitation". On the other hand, the prefix "over" means "above, beyond" and the word "exploit" is equivalent to using "to one's own advantage", generally, in an abusive way (abuse meaning ill usage, excessive or improper use). Thus, the term "overexploitation" implies excessive or improper use (transgressive), which is appropriate in this context; in contrast, "intensive use" can mean energetic but not transgressing the equilibrium state.

The author proposes that the term "intensive exploitation" be used to refer to the phase preceding overexploitation; thus, as a consequence of one, the other occurs. However, the first does not have to culminate in the second; one could have an intensive exploitation alternating with periods of nil abstraction that would never lead to overexploitation."

Further, the author presents a list of direct and indirect ***Negative impacts of overexploitation.*** *The distinction between the two categories (direct and indirect) is not clear and confusing. For example, the author lists among the direct impact of overexploitation "Change in the physical and chemical characteristics of the groundwater; hand in hand with the overexploitation, the groundwater abstracted sometimes becomes thermal and their chemical facies change, for example, going from bicarbonate to sulphate facies, or vice verse[sic!]" and then lists again, this time among the indirect impacts "Alteration of the physical properties of the aquifer water."*

The text now clarifies what is understood by direct impacts (effects with immediate economic repercussions) and indirect (effects that appear more slowly over time and have a more social, political and environmental scope); according to this, physical impacts can appear in one section or another.:

"3.1 Positive effects of intensive exploitation

- *Progressive economic development*. The district of Mazarrón (4 in Fig. 1) suffered economic depression between 1900 and 1950. In 1989, thanks to intensive exploitation of its aquifers (the Tagus-Segura water transfer scheme had not yet arrived), it achieved an agricultural production worth 102 M €, with a reported value of 67 M € (Aragón *et al*. 1992).

The real problem of overexploitation arises from the uncertainty of maintaining the socio-economic development in the long-term, especially if there is no prospect of external water resources being supplied to a particular area.

- *Infrastructure benefits* (water pipes, roads, electricity supplies, etc.).
- *Re-infiltration of excess irrigation water with recharge of the aquifer* when the abstracted water is applied to the same permeable terrain. In Vegas del Segura (5 in Fig. 1), the irrigation excess amounts to 25–35% of the water applied if the irrigation system is gravity-fed.
- *Recovery of saline soils* (as there is more water, there is greater solution).
- *Increase in vegetation cover*, which improves rainfall infiltration.
- *Change from a non-irrigated to an irrigated regime*, with all the related economic benefits.

3.2 Negative impacts of overexploitation

This section will differentiate between the direct and indirect impacts. Direct impacts are considered to be those whose effects are relatively rapid and which produce as a result certain serious consequences, fundamentally economic; in contrast, indirect impacts are considered to be those whose effects are more spread over time and more diffuse, and whose consequences are not only economic but also environmental, social, and political.

3.2.1 Direct

- *Continuous fall in piezometric levels*. This can be up to 10 m/y, as in the aquifer of Don Gonzalo-La Umbría (6 in Fig. 2); the sulfate content increased (Fig. 3) due to the action of the gypsum present at the aquifer limit (Andreu *et al*. 2004).

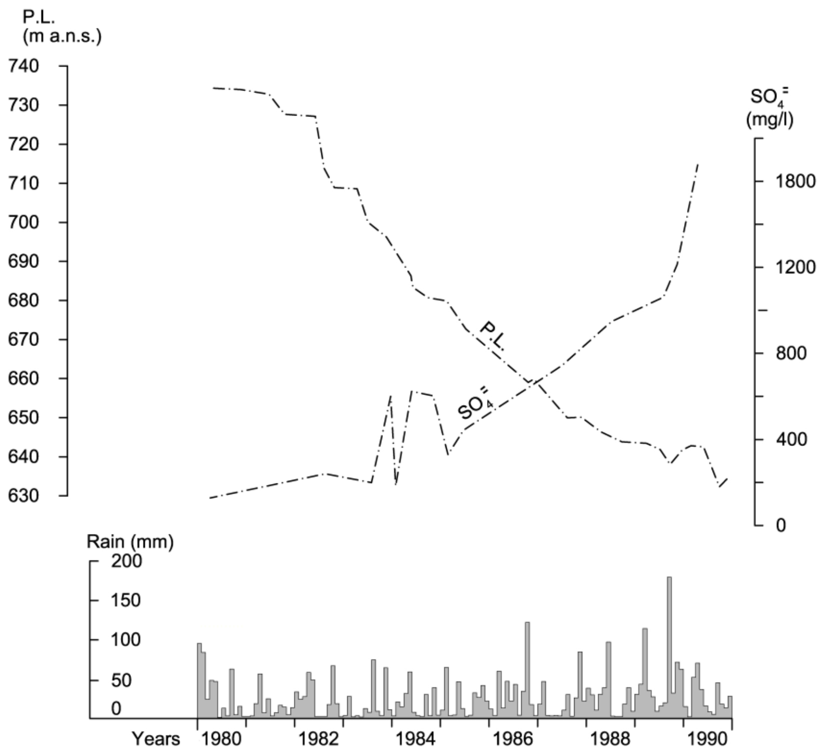

Fig. 3. Piezometrical Level and Sulphates Evolution in the Don Gonzalo-La Umbría Overexploited Aquifer.

- *Increase in the economic cost of pumping*. This has occurred in the Triassic aquifer Las Victorias ("7" in Fig. 2) and the aquifer of the Cabezón del Oro (province of Alicante), where the piezometric level now lies below 500 m (Fig. 4).

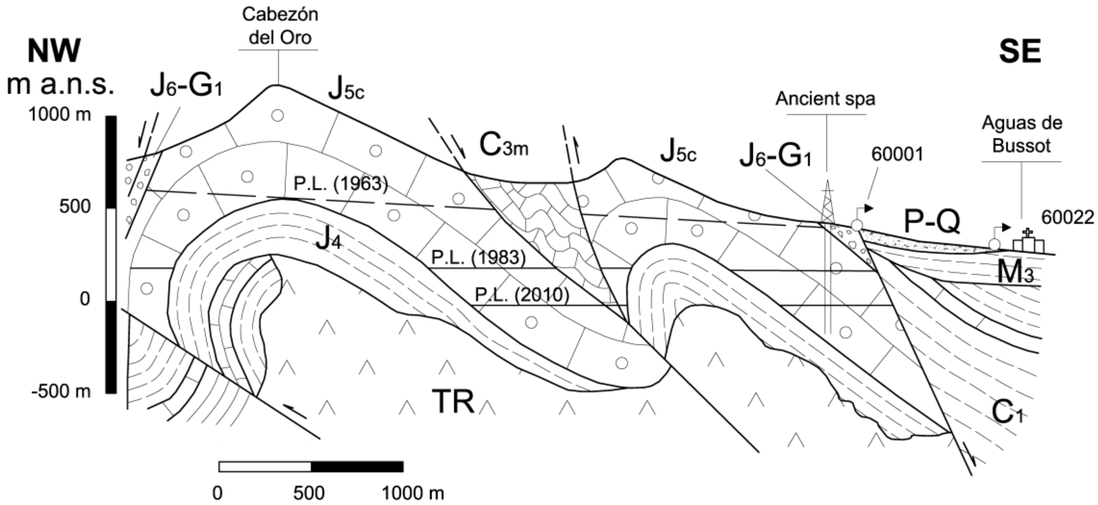

Fig. 4. Hydrogeological Section of the Cabezón del Oro Overexploited Aquifer. TR: Clay and gypsum. Triassic. J_4: Marly limestone. Middle Jurassic. J_{5c}: Oölitic limestone. Upper Jurassic. J_6-G_1: Sandstone. Upper Jurassic-Lower Cretace. C1: Marls. Lower Cretace. C_{3m}: Marly limestone. Upper Cretace. M_3: Marls. Upper Miocene. P-Q: Conglomerates. Pliocene-Quaternary.

- *Abandonment of wells*. In 1971 in the Ascoy-Sopalmo aquifer (the focus of this article), there were 146 production wells; by 1987, only 60 were still active, and now (2010) there are fewer than 20.
- *Diminishing groundwater reserves*. Between 1975 and 1981, 210 Mm^3 were taken from the reserves held in the Alto Guadalentín aquifer (Puerto Lumbreras and Lorca).
- *Induced compaction of the land surface* and appearance or accentuation of endorheic or semi-endorheic areas. Subsidence is occurring in the semi-arid zone -(Guadalentín), as evidenced by the collapse caused by "piping".
- *Compartmentalization of aquifers*. In 1973, the Quibas aquifer (8 in Fig. 2; Murcia and Alicante provinces) extended over 317 km^2 and was drained by the Chícamo spring (Fig. 5).

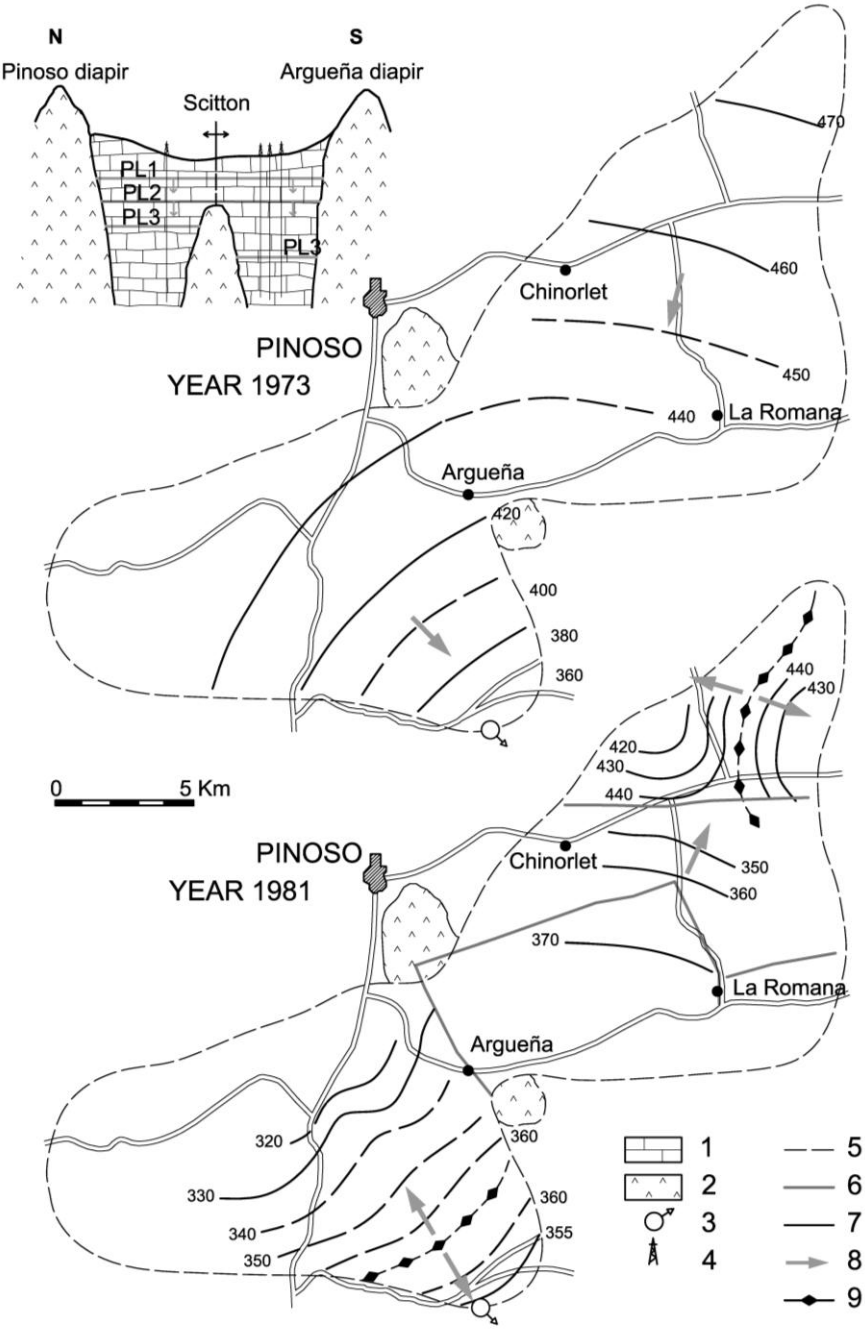

Fig. 5. Water-level contour maps and hydrogeological scheme of the Quibas aquifer. 1: Limestone. Eocene. 2: Clay and gypsum .Triassic. 3: Chícamo spring. 4: Boring. 5: Limit of aquifer. 6: Limit of subaquifer. 7: Water-level contour (m a.s.l.). 8: Groundwater flow. 9: Groundwater dividing.

In 1980, it split into seven distinct subaquifers, as the falling piezometric level sank below the top of the Triassic diapiric sub-outcrops (Rodríguez-Estrella 1979). The same thing has happened in the Ascoy-Sopalmo aquifer.

- *Change in the physical and chemical characteristics of the groundwater*. Of these, the following are considered:

A) NON-THERMAL AQUIFERS

A-1. CHEMICAL CHANGES

- *From a bicarbonate to a sulfate or chloride facies*: through lixiviation of continental evaporites, for example, Don Gonzalo-La Umbría aquifer; through marine intrusion, for example, Cabo Roig (Alicante province).
- *From a sulfate to a bicarbonate facies*: through the influence of endogenic CO_2, for example, Alto Guadalentín (Fig. 6). Highly mineralized waters, situated at depths, are propelled upwards by the action of the CO_2 and by the decrease in the hydrostatic pressure, and also as a consequence of the decrease in the piezometric levels (Rodríguez-Estrella *et al*. 1987).

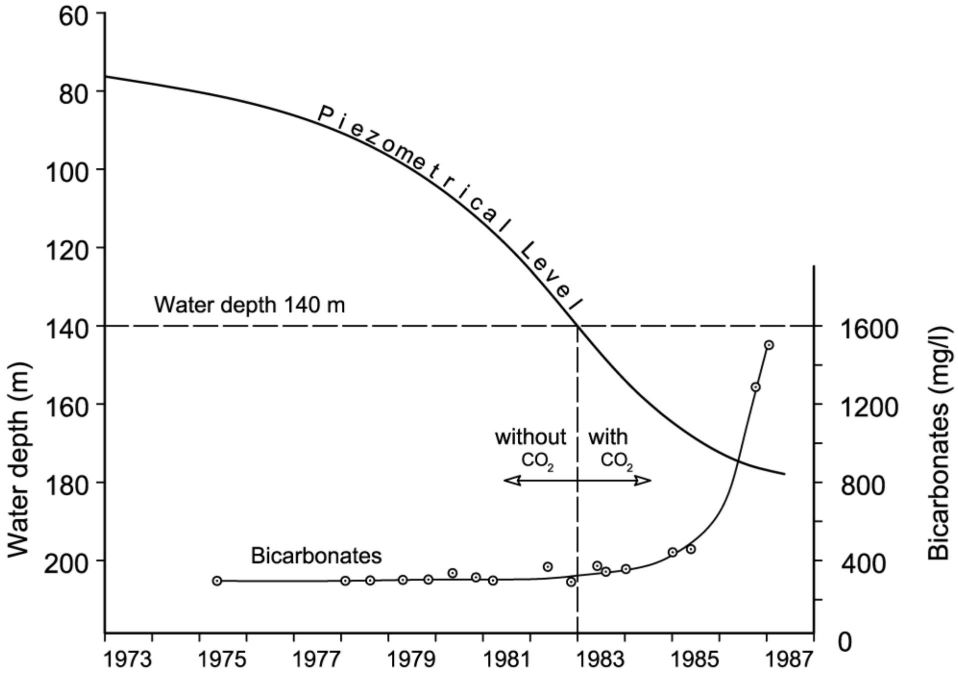

Fig. 6. Piezometrical Level and Bicarbonates Evolution in the Alto Guadalentín Overexploited Aquifer.

A-2. PHYSICAL CHANGES

- *Increase in temperature*, for example, Alto Guadalentín and Ascoy Sopalmo; in the latter, the confined nature of the aquifer combined with its depth means that below a certain depth the groundwater temperature increases, as do the degrees of dissolution and salinity.
- *Increase in turbidity and color, and change in smell and taste,* for example, Ventós (Alicante province).
- *Increase in conductivity.*

B) GEOTHERMAL AQUIFERS

B-1. CHEMICAL CHANGES

- *Confined metamorphic aquifer with CO_2*. Increases in sulfate, dry solids, and chlorides, and decreases in calcium and bicarbonates, for example, the Saladillo borehole (9 in Fig. 2), which consists of a thermal and emergent borehole (confined aquifer), of 535 m depth, which, with the passage of time, has gradually decreased in volume, remaining unaltered by pumping. This is because the emergent volume exceeds the renewable resources, since the main permeable rock does not come to the surface. In addition, between 1985 and 2003, the sulfates rose from 3093 to

3579 mg/l, the dissolved solids from 9340 to 9794 mg/l, and the chlorides from 1191 to 1269 mg/l; calcium fell from 713 to 344 mg/l and bicarbonates from 2068 to 1989 mg/l. This situation is "natural" overexploitation, not induced by people through pumping, but caused initially by people by the drilling of the borehole, leading to a slow emptying process of a semi-fossil aquifer.

- *Free carbonate aquifer without CO_2*. Increase in all parameters. For example, Baños de Alhama (10 in Fig. 2).

B-2. PHYSICAL CHANGES

- *Reduction in temperature*, for example, Saladillo borehole; between 1985 and 2003 the temperature decreased from 51 ºC to 49 ºC.
- *Increase in conductivity*, for example, the Baños de Alhama (10 in Fig. 2) borehole.
- *Modification induced in the river flow regime*. The Albacete hydrogeological unit is in a hydraulic connection with the Júcar River. As a result of overexploitation, the flow of the Júcar River fell from more than 11 m^3/s in 1975 to 5.2 m^3/s in 1989.
- *Impact or desiccation of wetlands and springs*. Numerous wetlands and an even greater number of springs have dried out as a consequence of overexploitation, both in the Albacete and Murcia provinces (López Bermúdez *et al*. 1988; Navarro *et al*. 1988).
- *Changes in groundwater extraction systems*. Examples include changes from ordinary wells (sometimes powered using the natural energy of windmills, as in the Campo de Cartagena) to boreholes; from springs to galleries; from boreholes to galleries, such as the well-known 2500 m Galería de los Suizos (Fig. 7) in the Crevillente aquifer (Alicante); and also from boreholes within a gallery (Solís *et al*. 1983).

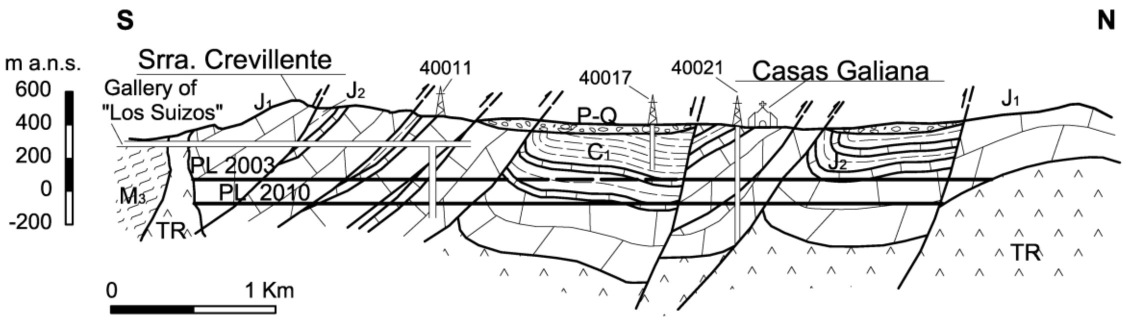

Fig. 7. Hydrogeological Section in the Sierra de Crevillente Overexploited Aquifer. TR: Clay and gypsum. Triassic. J_1: Dolomites. Lower Jurassic. J_2: Marls and limestones. Upper Jurassic. C_1: Marls. Lower Cretace. M_3: Marls. Upper Miocene. P-Q.: Conglomerates. Pliocene-Quaternary.

3.2.2 Indirect

- *Land subsidence and collapse*, giving rise to geotechnical impacts in dwellings (Cooper 1998). During the 1994 drought, numerous emergency wells were brought into operation in the Quaternary Vega Media aquifer in Murcia province. The consequence was a drop in piezometric levels of up to 7 m and land subsidence and ground collapse of up to 0.7 m, causing cracks to appear in buildings in the city of Murcia.
- *Pipeline breakages and deterioration of road surfaces.* Such damage is common in the Guadalentín Valley.
- *Salinization of soils*, for example, the Guadalentín Valley.

- *Progressive desertification*. In the Guadalentín Valley, erosion gullies and "soil piping" are common, indicating an advanced stage of desertification (Martínez-Mena *et al*. 2001).
- *Modification or suppression of flora*. Change from phreatophytes to xerophytes.
- *Disappearance of a particular fauna and substitution by another*. Substitution of the lacustrine avifauna by steppe birds in the Guadalentín Valley (Rodríguez-Estrella and López Bermúdez 1992).
- *Abandonment of agriculture and emigration from towns and villages*, for example, Yecla (Murcia).
- *Decline or disappearance of sheep herds*, for example, Yecla (Murcia).
- *Decline of hunting and angling*. With the disappearance of surface water, hunting and fishing also disappear.
- *Cessation of wetlands resources exploitation*, linked to the salt, clay, and mineral water spa industries.
- *Change in landscape and lack of correlation with ancient place names*, for example, the villages of Fuente Álamo or Fuente del Pino (Jumilla) no longer have *fuentes* (springs).
- *Alteration of the physical properties of the aquifer water* (water mixing, acceleration of karstification, reduced storage coefficient, etc.).
- *Creation of depression cones* that mobilize pollutants from remote areas.
- *Modification of the local climate* (the moderate climate of wetland areas).
- *Rise in the sea level of the Mediterranean:* the majority of the groundwater abstracted from coastal aquifers is destined for agriculture within the boundaries of either the same aquifer or adjacent ones. If the aquifer is overexploited, this necessarily means that part of the water extracted (precisely the part corresponding to the overexploitation) is never returned to these aquifers (hence the continual decline in reserves). This water must go somewhere and, given the coastal location, it is logical to suppose that it goes to the nearby Mediterranean Sea. Significant evaporation from the irrigated land (due to high temperatures) and plant transpiration means that the evaporated water vapor condenses and falls as rain over the sea. In other words, a large part of the "below ground" water is extracted and "donated" to the adjacent sea. In 1985, this author calculated the rise in sea level that could be produced by this means in the Mediterranean (which covers 1,000,000 km^2). The conclusion was that in the eastern third of the Mediterranean, the rise in sea level could amount to 0.5 mm/y, based on the fact that, in a year, overexploitation of the aquifers within 50 km of the Levante coast of Spain was 500 Mm^3. This issue is addressed here only as a working hypothesis, since, in order to confirm this effect, more detailed research would have to be carried out in relation to climate change as the main cause of sea level rise.
- *Legal problems* from impacts on water abstraction points.
- *Negative social, economic, and political impacts*. The Murcia Region has seen serious altercations, including a number of deaths related to water resource issues.
- *Disappearance or deterioration of landscape features or hydrological and hydrogeological features that formed part of the national heritage* (Rodríguez-Estrella 1999), including: old springs with associated archeological remains that have disappeared; unique ecosystems dependent on springs that have disappeared; ancient lakes with paleontological remains that have dried out; wetlands that have disappeared permanently and which have become dry saline areas; wetlands that have disappeared permanently, being transformed into agricultural areas; wetlands that have disappeared temporarily inside Natural Parks; unusual boreholes of scientific,

touristic, or educational interest (artesian and thermal wells) whose flow and temperature have decreased."

The discussion presented in chapter ***4.3 Chemical quality and thermalism*** *is woefully insufficient. The author is citing temporal changes in the aquifer chemical facies from "mixed sodium chloride-bicarbonate" or "sodium-calcium bicarbonate-chloride" in 1972 to "a sodium-chloride facies" in 1986 without presenting a single chemical analysis of all the major anions and cations in a tabular or graphic fashion. This is a major deficiency in the article.*

A table has been included in the manuscript to allow comparison of two hydrochemical analyses from the Fuente del Peral borehole, corresponding to 1974 and 2008, which includes all the major ions.:

Date	Facies	Ca	Mg	Na	K	Cl	SO_4	CO_3H	R.S.
10-10-1974	CO3H/Cl -Na	82	46	92	2	178	152	262	686
1-2-2008	Cl-Na	43	42	386	11	411	403	279	1.590

Table I. Chemical characteristics of Fuente del Peral borehole (10-10-1974 and 1-2-2008)

Elsewhere, he lists among the indirect impacts "Creation of depression cones that mobilize pollutants from remote areas", while cones of depression are clearly, always a direct result of ground-water production.

The "creation of depression cones that mobilize pollutants from remote areas" has been considered as an indirect impact, since pollution from "remote areas" occurs over time, whereas in the "nearby areas" the effect is almost immediate. Contamination is gradual and progressive, as indicated in the new Table I.

Strangely, the author also claims that "Sea level rise in the Mediterranean." is also an indirect result of aquifer overexploitation. I know of no mechanism that would explain how aquifer overexploitation may cause such dramatic effect.

This is a new hypothesis and as such, the relevant arguments have been included into the text, in response to questions raised by Referee 1.:

> *Rise in the sea level of the Mediterranean:* the majority of the groundwater abstracted from coastal aquifers is destined for agriculture within the boundaries of either the same aquifer or adjacent ones. If the aquifer is overexploited, this necessarily means that part of the water extracted (precisely the part corresponding to the overexploitation) is never returned to these aquifers (hence the continual decline in reserves). This water must go somewhere and, given the coastal location, it is logical to suppose that it goes to the nearby Mediterranean Sea. Significant

evaporation from the irrigated land (due to high temperatures) and plant transpiration means that the evaporated water vapor condenses and falls as rain over the sea. In other words, a large part of the “below ground” water is extracted and “donated” to the adjacent sea. In 1985, this author calculated the rise in sea level that could be produced by this means in the Mediterranean (which covers 1,000,000 km^2). The conclusion was that in the eastern third of the Mediterranean, the rise in sea level could amount to 0.5 mm/y, based on the fact that, in a year, overexploitation of the aquifers within 50 km of the Levante coast of Spain was 500 Mm^3. This issue is addressed here only as a working hypothesis, since, in order to confirm this effect, more detailed research would have to be carried out in relation to climate change as the main cause of sea level rise.

The author should keep in mind that not every reader of his article will be familiar with all the geographic locations and litho-stratigraphic units of his study area, and should always refer to the figures/maps where these locations or units are identified.

New references have been made to the corresponding figures where geographical and lithostratigraphic names are mentioned.

Last, but not least, the article needs a thorough editing, particularly with regard to the appropriate use of English language. The most flagrant examples of misuse of terms occur in chapter ***5 Proposal of internal actions to alleviate the hydric deficit of the Segura Basin. The term h****ydric is an adjective defined as relating to, characterized by, or requiring considerable moisture. Therefore, “hydric deficit” does not mean “scarcity of water” or “insufficient quantities or water”. Later in the same chapter the author is citing the need for “hydric education”, which doesn’t make any sense at all.*

As recommended by the referee, the article has undergone a rigorous revision both of its structure and of the use of English, which has been edited by a native English professional. The term “hydric deficit” has been substituted by “water deficit” and “hydric education” by “water education”.

Similarly, the caption of the chapter ***4.2 Analysis of the excision[sic!] of the Ascoy-Sopalmo aquifer*** *doesn’t make any sense either.*

The word “excision” has been replaced by “division”.

Elsewhere in the same chapter the author is referring to “surface river waters”, which is verbal overkill, as “river waters” are always understood as a component of “surface waters”.

The word “surface” has been removed.

Earlier, in the chapter ***4.1 General characteristics of the Ascoy-Sopalmo aquifer before division[sic!]*** *the author states that the aquifer “belongs to the municipalities of Jumilla and Cieza”, conveying an unintended connotation of legal property (while the author obviously intended to say that the aquifer is located beneath the area of the municipalities of…)*

The word “belongs” has been substituted by: “is located beneath the area of the municipalities of…”