The contribution of water REuse to a resourCe-efficient and sustainabLe wAter manageMent for irrigatiOn (RECLAMO)

Deliverable No.	**D1.1-PART II. Baseline report on the current state of reclaimed water reuse for irrigation in selected case studies** **D3.1. Model database**
Full title	**Current state of reclaimed water reuse for irrigation in selected case studies in Spain**
Work Package No. and Title	**WP1 – Knowledge base** **WP3- Integrated modeling**
Lead beneficiary	**Universidad Politécnica de Madrid (UPM)**
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Status	**Final**
Planned delivery date	**D1.1: 31/05/2021 (M12)** **D3.1: 31/07/2021 (M14)**
Actual delivery date	**31/05/2021 (M12)**
Dissemination level	**Public**
Project website	**https://blogs.upm.es/reclamo/**
Project start date and duration	**Start date of project: 01 June 2020** **Duration: 48 months**

The communication reflects only the author's view.

The project has received funds from the Spanish Ministry of Science and Innovation, State Research Agency. National Plan for Scientific and Technical Research and Innovation 2017-2020. Project R&D&i - Challenges 2019. Grant number PID2019-104340RA-I00.

TABLE OF CONTENTS

0. General remarks 5

1. Introduction 6

2. Los Auriles 7

2.1. Surface water bodies in the vicinity of Los Auriles 10

2.2. Groundwater bodies in Los Auriles area 12

2.3. Water balance in the Guadiana river basin 17

2.4. WWTP in los Auriles area 19

2.5. Water reuse in the Auriles area 20

3. Campo de Cartagena 21

3.1. Surface water bodies in the Campo de Cartagena area 26

3.2. Groundwater bodies in the Campo de Cartagena area 27

3.1. WWTP in the Campo de Cartagena area. 30

3.1. Water reuse in the Campo de Cartagena area 32

References 33

LIST OF FIGURES

Figure 1. Location of the study areas in Spain 6
Figure 2. Los Auriles location in the Eastern part of Guadiana River Basin. 7
Figure 3. Agrarian Demand Unit “Occidental II” characteristics. 8
Figure 4. Los Auriles local topography 9
Figure 5. Surface water bodies in Los Auriles Area 10
Figure 6. Groundwater bodies in Los Auriles area en el entorno de los Auriles. 13
Figure 7. Information Sheet of groundwater body “Mancha Occidental II”. 15
Figure 8. Water table level for piezometer 04.04.110 in groundwater body “Mancha Occidental II”. 16
Figure 9. Water table level for piezometer 2129-3-0008 in groundwater body “Mancha Occidental II” 17
Figure 10. Campo de Cartagena location within Segura River Basin District 21
Figure 11. Campo de Cartagena local topography. Green dots represent WWTPs. 22
Figure 12. Agrarian Demand Units at Campo de Cartagena (57, 58 y 75) and South Zone. 23
Figure 13. Irrigation piping network at Campo de Cartagena 24
Figure 14. Culture type distribution 24
Figure 15. Irrigation piping network at Campo de Cartagena 25
Figure 16. Surface and groundwater bodies in the Campo de Cartagena area. 26
Figure 17. Water table level for piezometer 07.31.099 in groundwater body “Campo de Cartagena”. 29
Figure 18. Nitrate concentration at borehole CA0731003 in groundwater body “Campo de Cartagena”. 30
Figure 19. WWTPs at Campo de Cartagena. 31
Figure 20. Destination of reused water at Segura river basin 32

LIST OF TABLES

Table 1. Status change limits of R-T05 water bodies, according to RD817/2015 11
Table 2. Status change limits of L-T25 water bodies, according to RD817/2015 12
Table 3. Minimum Ecological Flows for the surface water bodies in the vicinity of the Auriles .. 12
Table 4. Chemical status of groundwater body “Mancha Occidental II”. 17
Table 5. Water balance in the Guadiana river basin groundwater bodies. 18
Table 6. Excerpt of Resolution of February 6th 2019 of zones sensitive to euthrophication in the Guadiana River Basin. 19
Table 7. Concentration limits for physico-chemical pollutantas at Tomelloso WWTP 19
Table 8. Current water reuse in Guadiana River Basin 20
Table 9. Main water source of Campo de Cartagena Agrarian Demand Units. 23
Table 10. Water demand of Agricultural Demand Units at Campo de Cartagena. 24
Table 11. Status change limits of R-T13 water bodies, according to RD817/2015 27
Table 12. Authorized reuse volumes of WWTP at Campo de Cartagena 30
Table 13. Except of Resolution of February 6th, 2019 of zones sensitive to euthrophication in the Segura River Basin. 32

0. General remarks

This report is dedicated to presenting the current state of water reuse in selected case studies in Spain. It corresponds with D1.1-Part II 'Baseline report on the current state of reclaimed water reuse for irrigation in selected case studies' and D3.1 'Model database'. The first part of D1.1 'Baseline report on the current state of reclaimed water reuse for irrigation in Spain' (D1.1-Part I) is presented in a separate report.

This report is based on information compiled from various public databases, mainly the different River Basin Authorities and the Spanish Ministry of Environment (currently called 'Ministry for the Ecological Transtition and the Demographic challenge), and fieldworks carried out in the context of the RECLAMO Project. In March 2021, the UPM research team held a virtual meeting with representatives of the Irrigation Community of Campo de Cartagena to collect information and exchange ideas about water reuse in the region. Later, in April 2021, the UPM research team visited the Irrigation Community 'Los Auriles' (https://ceigram.upm.es/noticia/visita-de-investigadores-del-ceigram-a-los-auriles-en-el-marco-del-proyecto-reclamo/) and collected valuable information for modeling purposes.

1. Introduction

This report presents two case studies for potential water reuse (Figure 1): Los Auriles (Guadiana River Basin) and Campo de Cartagena (Segura River Basin), which are the case studies of the RECLAMO project.

Figure 1. Location of the study areas in Spain
Source: Own elaboration

These two case studies have been selected to illustrate very different contexts for reclaimed water reuse: the Segura river basin, which is at the forefront of water reuse for agriculture in Spain (and in Europe), and the Upper Guadiana river basin, with some success stories but little experience and low levels of water reuse.

2. Los Auriles

Los Auriles is located to the North of Tomelloso town in Ciudad Real province, Castilla la Mancha Autonomous Community, in the Eastern part of the Guadiana River Basin.

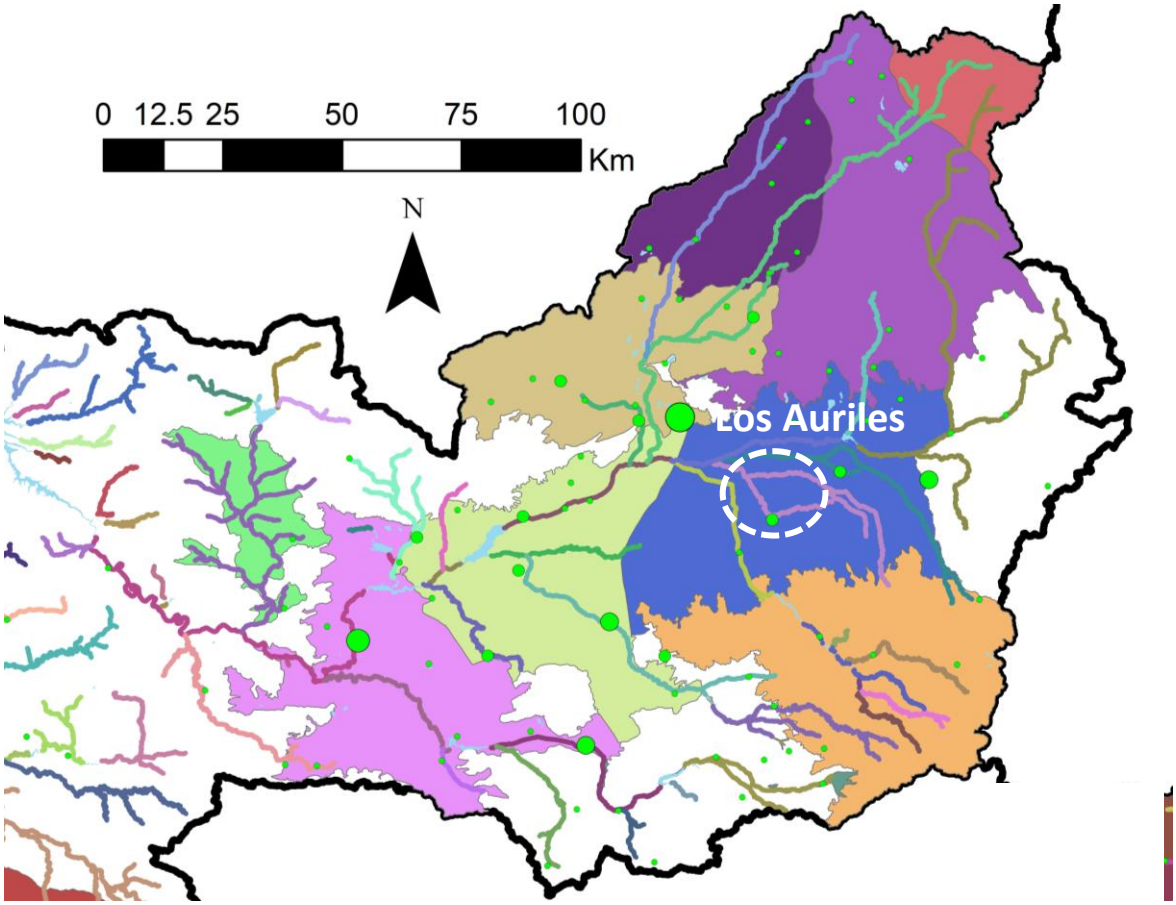


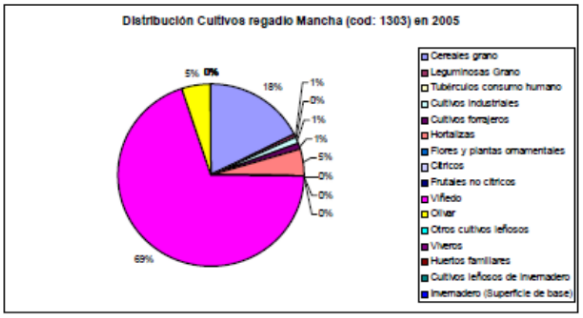
Figure 2. Los Auriles location in the Eastern part of Guadiana River Basin.
Note: Green dots show WWTP locations (diameter represents WWTP effluent flow)
Source: MITECO (2019).

Los Auriles is located in the Agrarian Demand Unit (UDA in the Spanish spelling) "Occidental II". Vineyard is the main crop in the UDA representing 840 hectares between 155 wine and olive growers, and the main water source is groundwater (Figure 3). Water demand is approximately 119 hm^3/year.

1. IDENTIFICACIÓN

Código	R4A	Nombre	OCCIDENTAL II
Sistema de Explotación	SISTEMA ORIENTAL (SUBS. ALTO GUADIANA)		

2. CARACTERÍSTICAS ESTRUCTURALES

	Situación Actual	Situación a 2021
Superficie Regable (ha)	74.304	59.406
Distribución de Cultivos		
Origen del Agua	Subterráneo	
Sistema de Riego	Goteo	
Eficiencia Aplicación	85,95%	

3. DEMANDA

	Situación Actual	Situación a 2021
Demanda Legal (hm3)	95,05	
Demanda Real (hm3)	118,89	100,75
Retorno (hm3)	9,28	7,86

4. NIVEL DE GARANTÍA

	Situación Actual	Situación a 2021
Garantía según ITPH	CUMPLE	CUMPLE
Garantía Volumétrica	100,00%	100,00%

5. VARIABLES ECONÓMICAS

	Situación Actual	Situación a 2021
Producción (kg/ha)	10.432,86	
Coste Producción (€/ha)	1.669,86	
Renta (€/ha)	768,80	
Margen Neto (€/ha)	633,70	
Beneficio (€/ha)	10,70	
Nº de Regantes	2.859	

Figure 3. Agrarian Demand Unit “Occidental II” characteristics.
Source: Guadiana River Basin Management Plan, Annex 4, Appendix 3 (Confederación Hidrográfica del Guadiana, 2016)

The area of study is mostly flat without large topographical landmarks and is drained to the Northwest by the water body “Cañada de la Urraca” (Figure 4).

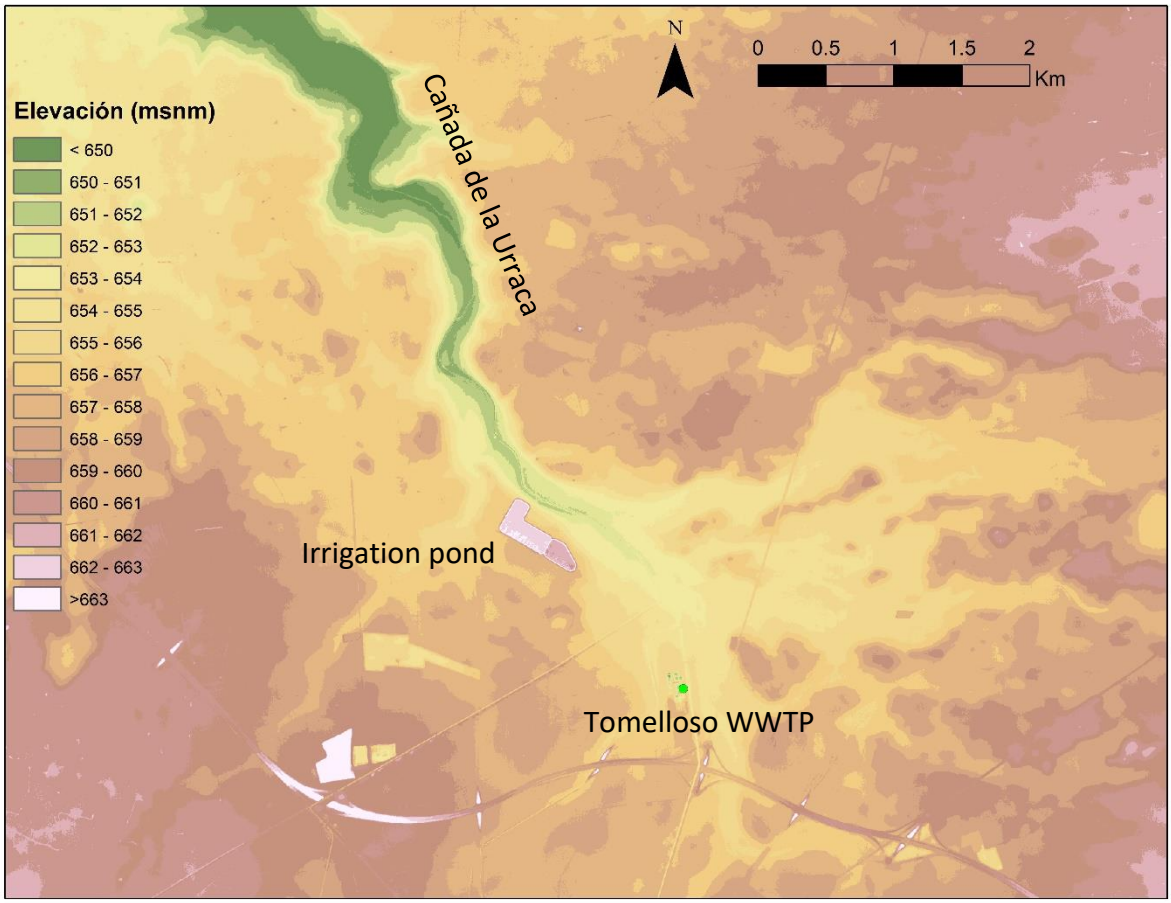


Figure 4. Los Auriles local topography.
Source: Instituto Geográfico Nacional (2020)

With respect to the local geology, the Report of sheet 739 of the Geological Map of Spain (Instituto Geológico y Minero, 2010) says:

“The oldest outcropping materials are from the Neogene. They are composed of limestones, marls and sands, which are usually covered by edaphic-sedimentary formations of limestone crusts. The most recent deposits -Pleistocene and Holocene- are gravels and sands of fluvial origin, sands and clay-sands of aeolian origin and saline muds; all of them occupy topographic depressions, such as the San Juan alluvial plain. "

2.1. Surface water bodies in the vicinity of Los Auriles

Los Auriles area (

Figure 5) is crossed by surface water body “Cañada de la Urraca” (ES040MSPF000134770). There are no flow gauging stations in the water body, according to the national gauging network (Red Oficial de Estaciones de Aforo, ROEA) managed by the Hydrographic Studies Centre (CEDEX, 2016). The water body discharges to the body “Río Záncara III” (ES040MSPF000142500), 17 km North of Tomelloso town. Then, Záncara river discharges to the water body “Río Guadiana-Cigüela” (Confederación Hidrográfica del Guadiana, 2016).

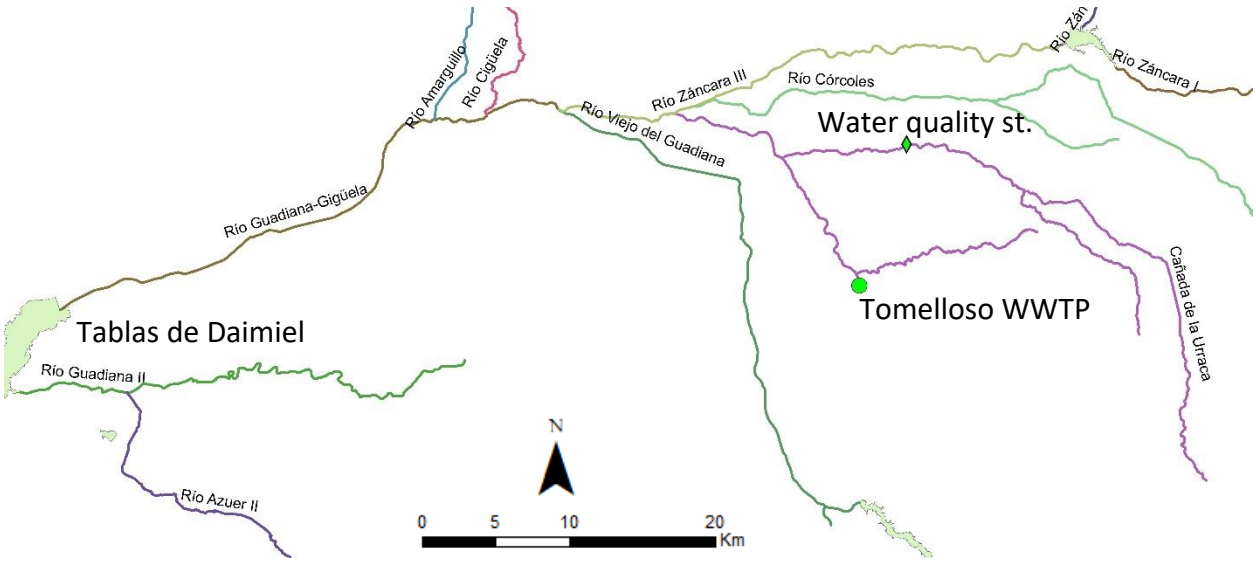


Figure 5. Surface water bodies in Los Auriles Area.
Source: Owen elaboration based on data from the Guadiana River Basin Management Plan (Confederación Hidrográfica del Guadiana, 2016)

All these water bodies are categorized under ecotype R-T05 “Ríos manchegos”. Table 1 shows the status change limits for the biological, physico-chemical and hydromorphological elements. To achieve the good ecological status, ammonium concentration should remain below 0.6 mg/l, nitrate concentration below 25 mg/l and phosphate concentration below 0.4 mg/l.

Table 1. Status change limits of R-T05 water bodies, according to RD817/2015

TIPOS RÍOS	INDICADOR	UNIDADES	CONDICIÓN DE REFERENCIA/ CONDICIÓN ESPECÍFICA DEL TIPO	LÍMITES DE CAMBIO DE CLASE DE ESTADO *Indicadores biológicos e hidromorfológicos: RCE* *Indicadores químicos: MEDIDA*			
				Muy bueno/ bueno	Bueno/ moderado	Moderado/ deficiente	Deficiente/ malo
R-T05	IBMWP	-	123	0,89	0,54	0,32	0,13
R-T05	IMMi-T	-	1	0,826	0,682	0,455	0,227
R-T05	IBMR	-	10	0,90	0,68	0,45	0,23
R-T05	IPS	-	15,9	0,92	0,69	0,46	0,23
R-T05	QBR	-	58	0,862			
R-T05	pH	-		6,5-8,7	6-9		
R-T05	Oxígeno	mg/L			5		
R-T05	% Oxígeno	%		70-100	60-120		
R-T05	Amonio	mg NH_4/L		0,2	0,6		
R-T05	Fosfatos	mg PO_4/L		0,2	0,4		
R-T05	Nitratos	mg NO_3/L		20	25		

Source: MAPAMA (2015)

There exists a water quality station in the northern branch of “Cañada de la Urraca” water body, under designation “Arroyo de San Gregorio Ctra Tomelloso-Alcázar” (GN00000600). Annex 9 of Guadiana River Basin Management Plan (Confederación Hidrográfica del Guadiana, 2016) declares that “Cañada de la Urraca” (ES040MSPF000134770) water body presents a good Chemical status but less than good Ecological status, implying a less than good water body status. The fact that the water quality station in located in the northen branch may indicate that the pressures that drive this status are not related with nonpoint pollution from Los Auriles or point pollution from Tomelloso Wastewater Treatment Plant (WWTP), which are located in the southern branch (

Figure 5)

Guadiana-Cigüela water body discharges to lentic mass Tablas de Daimiel (ES040MSPF004000620), ecotype L-T25. The fact that Tomelloso WWTP is in the catchment area of this lentic water body implies additional restrictions on the concentration of nutrients allowed in the WWTP effluent.

Table 2. Status change limits of L-T25 water bodies, according to RD817/2015

TIPOS LAGOS	INDICADOR	UNIDADES	CONDICIÓN DE REFERENCIA/ CONDICIÓN ESPECÍFICA DEL TIPO	LÍMITES DE CAMBIO DE CLASE DE ESTADO *Indicadores biológicos : RCE* *Indicadores químicos: MEDIDA*			
				Muy bueno/ bueno	Bueno/ moderado	Moderado/ deficiente	Deficiente/ malo
L-T25	IBCAEL	--	6,19	0,78	0,59	0,39	0,2
L-T25	Riqueza macrófitos	Nº de especies	23		0,48	0,27	0,1
L-T25	Cobertura macrófitos eutróficas	%	0	0,99	0,9	0,5	0,3
L-T25	Cobertura macrófitos exóticas	%	0	1	0,95	0,75	0,5
L-T25	Cobertura helófitos	%	80	0,88	0,75	0,37	0,13
L-T25	Cobertura hidrófitos	%	90	0,83	0,55	0,28	0,01
L-T25	pH	--			(7,5 – 10)	(≤7,5 ó ≥ 10)	

Source: MAPAMA (2015)

Before analyzing the quantity of WWTP effluent that could be reused, the effect on receiving waters should be considered. Table 3 shows the minimum Ecological Flows fixed by the Guadiana river basin authorities in the current River Basin Management Plan.

Table 3. Minimum Ecological Flows for the surface water bodies in the vicinity of the Auriles

CODIGO	NOMBRE	CAUDALES ECOLOGICOS (hm3)											
		OCT	NOV	DIC	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP
13476	RIO VIEJO DEL GUADIANA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13477	CAÑADA DE LA URRACA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14250	RIO ZANCARA III	0.003	0.002	0.005	0.001	0.008	0.000	0.014	0.002	0.000	0.000	0.000	0.000

Source: Confederación Hidrográfica del Guadiana (2016)

The table shows that there are no flow restrictions on any of the surface water bodies in the summer months (June-September), and that low minimum flows are fixed only for Zancara III water body in the October-may period.

2.2. Groundwater bodies in Los Auriles area

Los Auriles area is located on groundwater body "Mancha Occidental II" (ES040MSBT000030611), with an extension of 2536 km^2 and composed by two superposed aquifers.

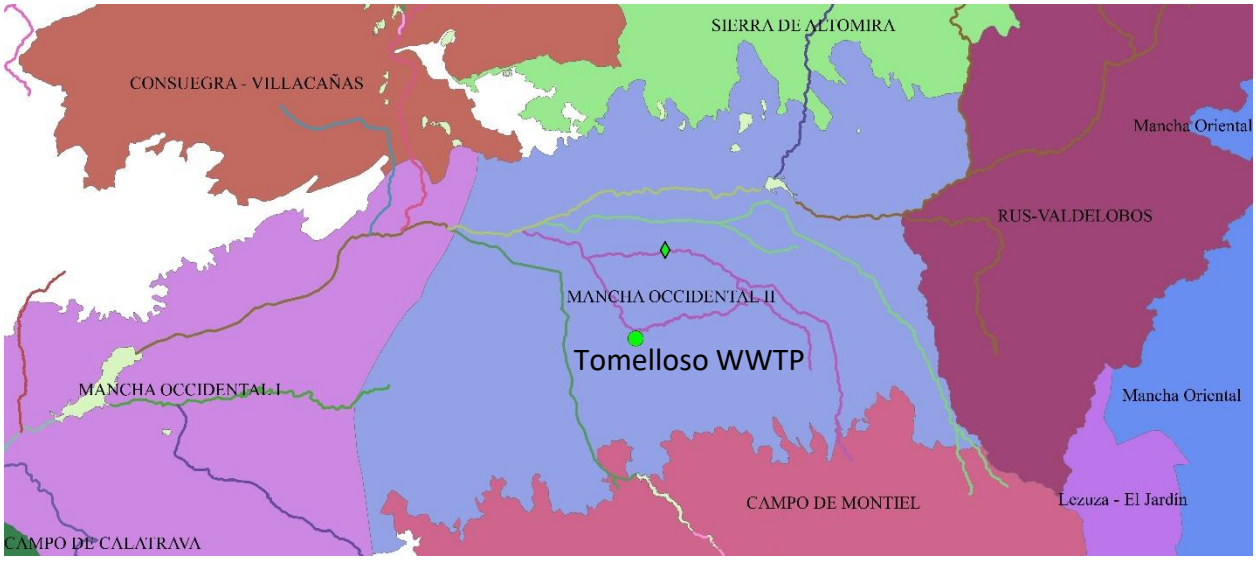


Figure 6. Groundwater bodies in Los Auriles area en el entorno de los Auriles.
Source: Confederación Hidrográfica del Guadiana (2016)

Hydrogeology notes on the Spanish Geological map (Instituto Geológico y Minero, 2010) explain that:

"The Sheet covers an area belonging to System 23 (Plain of La Mancha) according to the national numbering of the Aquifer Systems.

Within the Sheet there are two main hydrogeological units:

- Top unit

- Lower unit

The Upper Unit is formed by the calcareous section of the Upper Miocene and by more modern terrigenous materials (Pliocene and Quaternary).

The calcareous section is an important aquifer that extends outside of system 23, both in the upper Guadiana basin and in the middle. It is a free aquifer fed by direct rain infiltration and laterally by neighboring aquifer systems; its natural outlets are evaporation and drainage to the Guadiana River.

The lower Unit is composed of calcareous and dolomitic, Jurassic and Cretaceous materials and is the continuation below the Upper Unit of the Mesozoic materials of Campo de Montiel (System 24). It is a free aquifer in Campo de Montiel and semi-confined in the Plain of La Mancha; Its feeding is related to recharge by rain in Campo de Montiel, or through the upper level and the lateral aquifer systems.

In the hydrogeological bibliography an intermediate level is cited between both units that would correspond to those thick and fine detrital sections of the tertiary materials, but their

arrangement and relationship both at the Sheet level and at the regional level is difficult to determine.

Water resources are focused on the agricultural sector, where demand has increased to a high degree due to the change from vineyard and low profitability agriculture to widely extended irrigation."

Figure 7 shows the Information Sheet of the groundwater body prepared by Guadiana River Basin Authority.

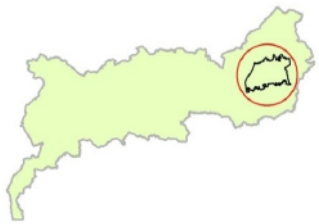
Fichas de caracterización de las Masas de Agua Subterránea en la DHGn		
Mancha Occidental II		
Código	041.006	
Superficie Poligonal (km^2)	2536	
Situación	Comunidad Autónoma de Castilla La Mancha. Provincias de Albacete, Cuenca, Ciudad Real y Toledo. Zona Oriental de la Cuenca del Guadiana (Alto Guadiana).	
Litología	Pizarras y cuarcitas paleozoicas (>800 m). Calizas, dolomías, gravas y areniscas mesozoicas (Mesozoico de Altomira y Montiel: 700 m). Arcillas y yesos del Paleógeno (70-200 m). Calizas y calizas lutíticas del Neógeno (hasta 97 m). Sedimentos detríticos del Neógeno (gravas, arenas, areniscas, lutitas: hasta 300 m).	
Acuíferos	En el sistema se diferencian dos acuíferos superpuestos: Superior formado por materiales del Terciario y Cuaternario en régimen libre. Inferior formado por materiales mesozoicos en régimen confinado.	
Geología e Hidrogeología	La LLanura Manchega forma una depresión que ocupa la parte meridional de la submeseta castellana Sur, rodeada de relieves de sierras paleozoicas y mesozoicas. Corresponde a un relleno de materiales continentales (Miocenos y Pliocuaternarios) recubiertos parcialmente por rañas, piedemontes y por cuaternarios muy característicos. El sustrato de la depresión está formado por un zócalo Paleozoico de baja permeabilidad, sobre el que se desarrolla en discordancia el Triasico, Jurásico, Cretácico y Paleógeno. Este conjunto de materiales paleozoicos y mesozoicos son prolongación de las unidades geológicas vecinas (montes de Toledo, Campos de Montiel y Sierra de Altomira). Las aguas subterráneas han sido intensamente explotadas desde mediados de los años 80 del pasado siglo, provocando afecciones importantes en el régimen de los ríos y a las zonas húmedas dependientes.	
Zona no Saturada	Depósitos detríticos cuaternarios y terciarios, y depósitos carbonatados del Mioceno superior.	
Limites de la masa	Limita al N con las alineaciones carbonatadas de la Sierra de Altomira en contacto con los materiales terciarios de la fosa manchega. El límite oriental se define en la divisoria de aguas subterráneas que separa flujos hacia el Este y hacia el Oeste. Limita al S con los afloramientos carbonatados de materiales jurásicos y cretácicos del Campo de Montiel. El límite O se sitúa en la línea que marca el acuñamiento de los materiales mesozoicos que forman el acuífero inferior mesozoico.	
Recarga	A través de la infiltración del agua de lluvia; de la infiltración de aguas superficiales de los ríos Záncara, Corcoles y Guadiana; de las aportaciones laterales de las masas de Altomira y Consuegra-Villacañas, al N, Campo de Montiel, al S; y Rus-Valdelobos, al este; y retornos de riego.	
Descarga natural	Debido a la alteración, actualmente no existen descargas naturales significativas, a excepción del flujo subterráneo que se produce hacia la masa Mancha Occidental I.	
Recurso total diponible (PH 2010-15): 106,2 hm3/año		Indice de explotación (PH 2010-15): 3,18
Vulnerabilidad a la contaminación	Prodominio de grado bajo y grado muy bajos en las zonas de bordes sur y norte. Llanuras aluviales con valores medios y altos.	
Ecosistemas acuáticos y ecosistemas terrestres dependientes de MASb (LICs, ZEPA, etc)		
Ríos: Guadiana, Záncara, Córcoles, Cañada de la Hurraca.		
LIC y ZEPA: Humedales de la Mancha (Lagunas de Pedro Muñoz,		
de Sánchez Gómez y Dehesilla, de Manjavacas, de Alchozo, del Taray Chico,		
Pantano de Los Muleteros: (S4250010-ES0000091). Reserva de la Bosfera: La Mancha Húmeda.		

Figure 7. Information Sheet of groundwater body “Mancha Occidental II”. Source: Confederación Hidrográfica del Guadiana (2016)

Groundwater body “Mancha Occidental II” is declared as having a poor Quantitative status and a poor Chemical status.

Annex 9 of Guadiana River Basin Management plan declares that the available renewable resource for “Mancha Occidental II” groundwater body amounts to 106.2 hm^3/year, while the water rights conceded amount to 337.5 hm^3/year, resulting in an exploitation index of 3.18, above the 0.8 value that is considered the limit. Nevertheless, it seems that current abstraction is below the total water rights and the water table has remained stable in the past years Mitecord (2020).

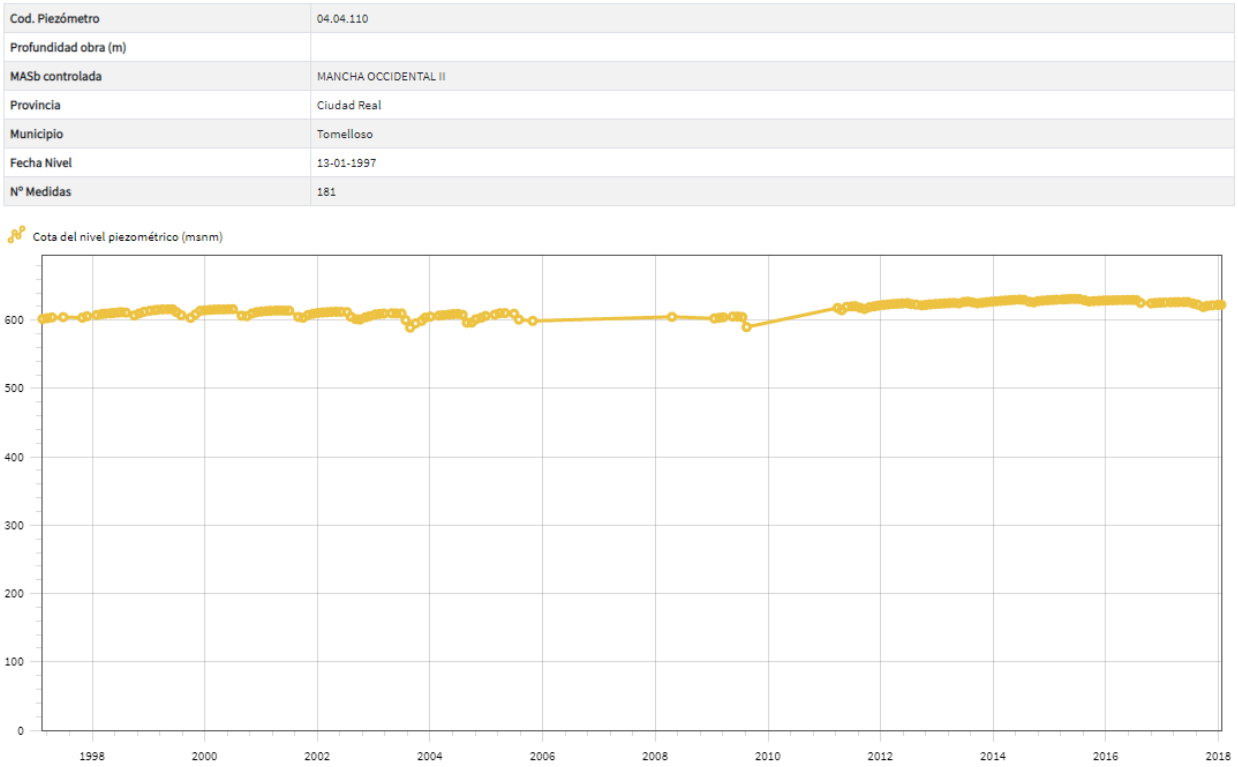


Figure 8. Water table level for piezometer 04.04.110 in groundwater body “Mancha Occidental II”.
Source: Mitecord (2020)

Before the restriction on extractions (see following paragraph), the water table level was sinking at a fast pace (Figure 9).

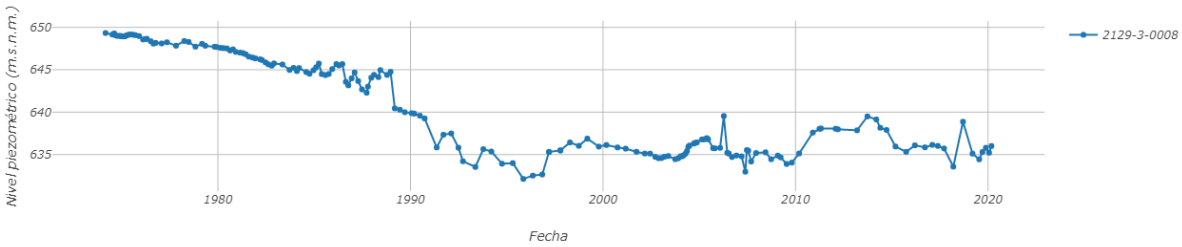


Figure 9. Water table level for piezometer 2129-3-0008 in groundwater body "Mancha Occidental II".
Source: IGME (2020)

With respect to the Chemical status, the nitrate concentration limit was not respected in 42% of control points, and several Environmental Quality Norm concentrations limits were not respected: 0.116 μg/l of Alaclor plaguicide in 2011 and 0.11 μg/l of Desisopropilatrazina in 2009.

Table 4. Chemical status of groundwater body "Mancha Occidental II".

Cód. masa	Denominación	Criterios de valoración y resultados						
		1	2	3	4	5	6	7
30611	MANCHA OCCIDENTAL II	BUENO	MALO	BUENO	BUENO	BUENO	BUENO	MALO

Clave valoración:

1. Sustancias activas de los plaguicidas
2. Nitratos
3. Parámetros con valor umbral.
4. Salinización u otras intrusiones
5. Disminución significativa de la calidad química y ecológica de las masas asociadas de aguas superficiales, producida por la transferencia de contaminantes procedentes de la masa de agua subterránea
6. Daño significativo a los ecosistemas terrestres dependientes de las MaSb producido por la transferencia de contaminantes
7. Cumplimiento de las disposiciones del artículo 7(3) de la DMA (zonas protegidas para la captación de agua potable).

Source: Confederación Hidrográfica del Guadiana (2016)

2.3. Water balance in the Guadiana river basin

In order to put the local groundwater balance in context, this paragraph presents the quantitative status of the groundwater bodies in the Guadiana river basin, and the actions taken by the river basin authority to cope with the overextraction problems.

Table 5. Water balance in the Guadiana river basin groundwater bodies.

Groundwater body	*Available renewable resource (hm3/year)*	*Water extraction permits (hm3/ year)*	*Exploi-tation index (Ie)*	*Balance (hm3/ year)*	*Approx. Treated wastewater (hm3/ year)*
SIERRA DE ALTOMIRA	26	31.51	1.21	-5.51	1.9
LA OBISPALÍA	2.3	1.23	0.53	1.07	0.0
LILLO-QUINTANAR	17	20.97	1.23	-3.97	3.1
CONSUEGRA-VILLACAÑAS	28	47.73	1.7	-19.73	48.0
RUS-VALDELOBOS	24.6	70.36	2.86	-45.76	10.9
MANCHA OCCIDENTAL II	106.2	337.53	3.18	-231.33	11.8
MANCHA OCCIDENTAL I	91.2	327.39	3.59	-236.19	25.3
CAMPO DE MONTIEL	9	30.36	3.37	-21.36	3.3
BULLAQUE	19.6	7.15	0.36	12.45	1.1
CAMPO DE CALATRAVA	19.9	63	3.17	-43.1	29.8
ALUVIAL DEL JABALÓN	1.5	2.15	1.43	-0.65	0.8
ALUVIAL DEL AZUER	0.8	4.19	5.24	-3.39	0.2
LOS PEDROCHES	4.2	2.3	0.55	1.9	6.1
CABECERA DEL GÉVORA	2.3	0.2	0.09	2.1	0.5
VEGAS BAJAS	68.9	6.9	0.1	62	34.1
VEGAS ALTAS	64.8	9.7	0.15	55.1	9.1
TIERRA DE BARROS	25.6	20.9	0.82	4.7	3.0
ZAFRA-OLIVENZA	37.9	3.8	0.1	34.1	3.3
AROCHE-JABUGO	4.6	0.8	0.17	3.8	2.0
AYAMONTE	9.6	4.5	0.47	5.1	6.6

Source: Own elaboration based on data from the Guadiana River Basin Management Plan (Confederación Hidrográfica del Guadiana, 2016)

¡Error! No se encuentra el origen de la referencia. shows the water balance for each g roundwater body considering the available renewable resources (second column) and the water permits (third column).

In the case of groundwater bodies shaded in brown, the river basin authority has restricted water abstractions to match the available renewable resources. Therefore, permitted irrigation for "herbaceous-type" crops ranges between 2000 and 2200 m3/ha/year; in the case of permanent crops it is restricted to 1500 m3/ha/year.

The last column shows the available volume of treated water in the WWTPs above each of the groundwater bodies. Additional checks are needed to make sure if any of this volume would be needed for ecological flows in the surface bodies downstream of each WWTP.

2.4. WWTP in los Auriles area

The closest WWTP to los Auriles is the Tomelloso plant (uwwCode ES8130820002010E), with a nominal load of 40'627 population equivalent and a capacity of 90'000 p-e. European Commission (2019).

Since the treatment plant is in the catchment area of the Tablas de Daimiel water body, the Resolution of February 6th, 2019 applies restrictions to Phosphorus emissions, and an additional treatment that should be specified in the Discharge Permit.

Table 6. Excerpt of Resolution of February 6th 2019 of zones sensitive to euthrophication in the Guadiana River Basin.

Descripción de la zona sensible						Aglomeraciones urbanas mayores de 10.000 habitantes equivalentes		
Código	Nombre	Masa de agua	Criterio de designación	Fecha de la declaración	Zona de captación	Nombre	Código	Comunidad Autónoma
ESRI442	Parque Nacional de lasTablas de Daimiel.	ES040MSPF004000620	aP, c	30/06/1998	ESCM442	Argamasilla de Alba.	ES8130190001010	Castilla-La Mancha.
						Daimiel.	ES8130390001010	
						Herencia.	ES8130470001010	
						Manzanares-Membrilla.	ES8130530003010	
						Socuéllamos.	ES8130780001010	
						La Solana.	ES8130790001010	
						Tomelloso.	ES8130820002010	
						Villarrubia de los Ojos.	ES8130960001010	
						Consuegra.	ES8450530001010	
						Madridejos.	ES8450870001010	
						Quintanar de la Orden.	ES8451420001010	

Source: Ministerio para la Transición Ecológica (2019)

Therefore, given the size of the WWTP (between 10'000 and 100'000 p-e) and the additional restrictions included in the water discharge permit, the physico-chemical pollutant limits are (RD 509/1996 and RD 2116/1998). WWTP below 10´000 p-e have no restrictions.

Table 7. Concentration limits for physico-chemical pollutantas at Tomelloso WWTP

	Maximum concentration at discharge (mg/l)
Biochemical Oxygen Demand (BOD5)	25
Chemical Oxygen Demand (COD)	125
Total Suspended Solids (TSS)	35
Total Phosphorus	2
Total Nitrogen	15

Source: Own elaboration based on data from RD509/1996 and RD 2116/1998

2.5. Water reuse in the Auriles area

It has been shown in previous paragraphs that the implementation of a wastewater reuse projects requires a concession or authorization by the River Basin Authority. The Authority should verify that each new project is compatible with a sustainable management of the water cycle.

Section 2.8.1 of the Guadiana River Basin Management Plan "Non-conventional resources" (Confederación Hidrográfica del Guadiana, 2016) presents the current reuse volume (Table 8), and declares that *"in the deficit areas, and especially in the Upper Guadiana Basin, water reuse will exclusively be allowed to substitute irrigation or industrial water rights"*. That is, that water reuse should be a relief to the existing abstraction, and not a net increase in the water offer. In other areas of the River Basin a reuse project would not be subject to this restriction, but it is probable that the users would seek more economic water sources.

Table 8. Current water reuse in Guadiana River Basin

WWTP	*Reused volume (hm^3/year)*
Ciudad Real	2.37
Alcázar de San Juan	4.75
Tomelloso	1.27
La Solana	0.70
Llerena	0.04
Total	9.13

Source: Own elaboration based on data from the Guadiana River Basin Management Plan (Confederación Hidrográfica del Guadiana, 2016)

The totality of this reused volume has been used for agricultural purposes MITECO (2019).

The Auriles irrigation community is located northeast of the town of Tomelloso (39.2096163691243, -3.0150085064947034). The project was funded 50% by the community of Castilla la Mancha and 50% by producers with 8-year financing. Reclaimed water for irrigation is stored in two reservoirs that are connected to the Tomelloso wastewater treatment plant (WWTP) by the Auriles channel. One of the reservoirs has the capacity to irrigate 700 ha, the other 14ha. The volume of water stored in both reservoirs is 500,000 $m^{3.}$ They cover a surface area of 90,000 m2 and have an average depth of 9.5 m. They have volume control using 700mm floating probes as well as ultrasonic wave technology for algae control.

Regarding the distribution of water from the reservoirs to the irrigation sites, there is a pumping system with 3 152 hp pumps plus a fourth reserve, and a speed variator to adapt the curve of the pumps to the demand. The maximum supply capacity is 400 l/s with a maximum pressure of 7 bar. There is one hydrant every 9 ha in production.

The price of reclaimed water consists of a fixed cost of 60 euros per monthly hectare per producer plus a variable cost of 0.06-0.08 eur/m3 (it depends on the energy cost).

3. Campo de Cartagena

Campo de Cartagena is located to the North of the homonym city, in the South Eastern part of the Segura River Basin District (Figure 11).

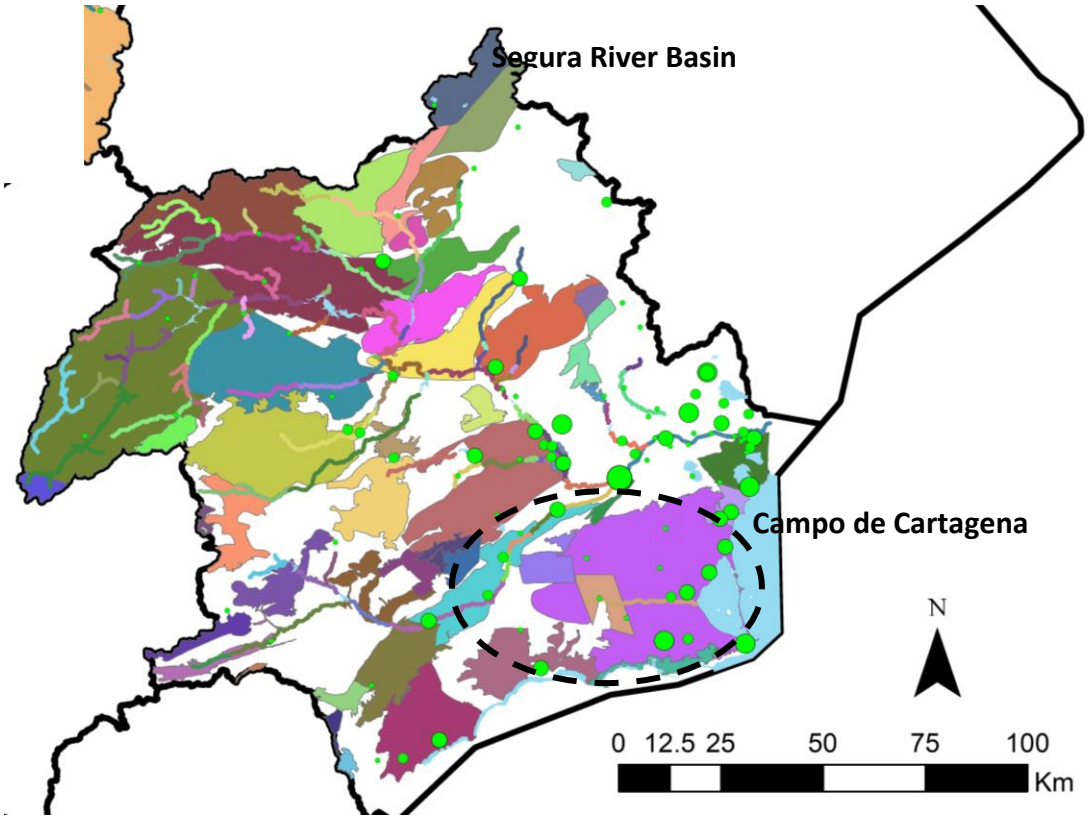


Figure 10. Campo de Cartagena location within Segura River Basin District
Source: Confederación Hidrográfica del Segura (2016)

Local topography shows a continuous slope to the East where the Mar Menor coast is located (Figure 11). The irrigated area has a surface of 33'000 ha (Ródenas, 2010). The water is supplied by the Tagus-Segura Transfer and reused water from local WWTPs, then distributed through more than 900 km of pressurized pipes that feed drip irrigation systems, with an average consumption of 3500 m^3/ha/year (Ródenas, 2010).

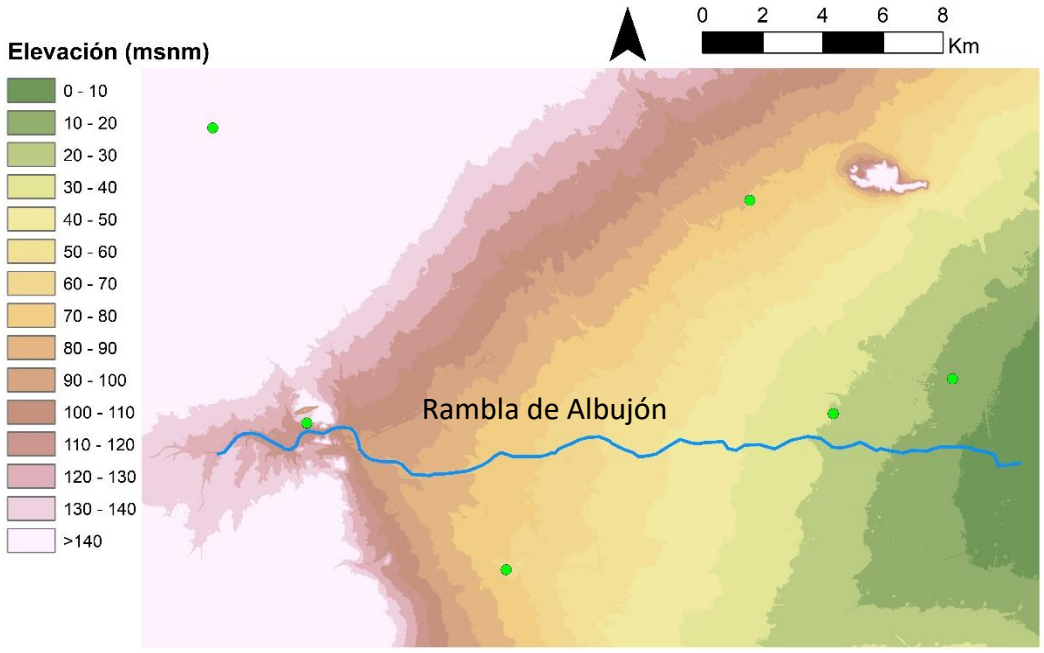


Figure 11. Campo de Cartagena local topography Green dots represent WWTPs. Source: Instituto Geográfico Nacional (2020)

With regards to the local geology, the Report of Sheet 955 of the Geological Map of Spain locates Campo de Cartagena in the Mar Menor Neogen-Quaternary geological basin, on the Baetic area. Torre Pacheco geological basin is thought to have more than 3000 m of Miocene series, with glacis, black and red silt and crust pebbles in the surface.

According to the Segura River Basin Management Plan, 89 hm^3/year are extracted from the Campo de Cartagena aquifer, corresponding to all the renewable ressources available.

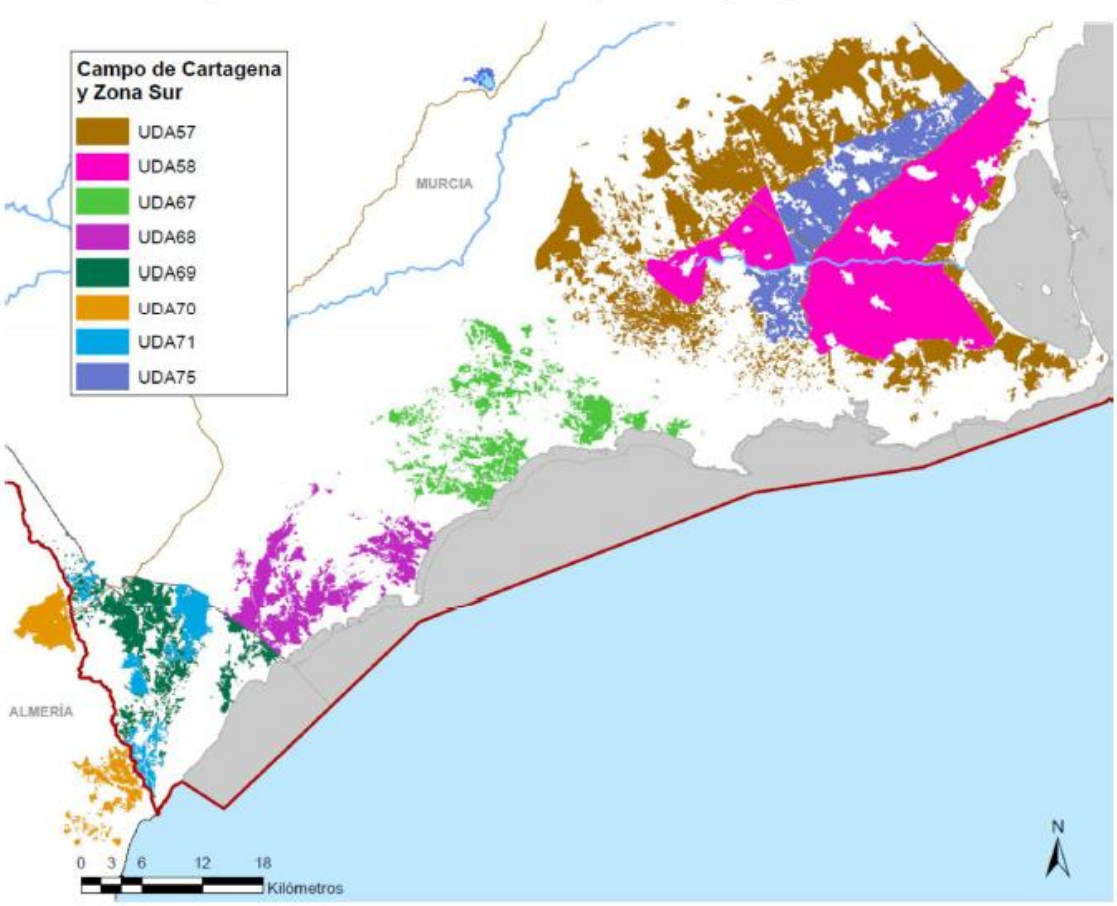


Figure 12. Agrarian Demand Units at Campo de Cartagena (57, 58 y 75) and South Zone.
Source: Confederación Hidrográfica del Segura (2016)
Note: TTS (Transvase Tajo-Segura): Tagus-Segura water transfer; ZRT (Zona Regable Transvase): Irrigated area of the water transfer; ATS (Acueducto Tajo-Segura): Tagus-Segura aqueduct.

Source: Confederación Hidrográfica del Segura (2016).

Table 10. Water demand of Agricultural Demand Units at Campo de Cartagena. and Table 10 show respectively the main water sources and the yearly water demand for each Agrarian Demand Unit.

Table 9. Main water source of Campo de Cartagena Agrarian Demand Units.

UDA	Denominación	Municipios	Origen recurso
57	Resto Campo de Cartagena, regadío mixto de acuíferos, depuradas y desalinizadas	Varios Zona Campo de Cartagena	Subterráneo/ Depurado/ Desalinización
58	Regadíos redotados del TTS de la ZRT Campo de Cartagena	Varios Zona Campo de Cartagena	ATS/ Subterráneo/ Depurado

75	Cota 120 Campo de Cartagena	Varios Zona Campo de Cartagena	Subterráneo/ Depurado/ Superficial/ Desalinizado

Note: TTS (Transvase Tajo-Segura): Tagus-Segura water transfer; ZRT (Zona Regable Transvase): Irrigated area of the water transfer; ATS (Acueducto Tajo-Segura): Tagus-Segura aqueduct.
Source: Confederación Hidrográfica del Segura (2016).

Table 10. Water demand of Agricultural Demand Units at Campo de Cartagena.

UDA	*Gross demand (hm^3/year)*	*Net demand (hm^3/year)*
57	87.3	72.8
58	131.8	107.1
75	39.4	33.2

Source: Own elaboration based on data from the Segura River Basin Management Plan (Confederación Hidrográfica del Segura, 2016).

In the case of Campo de Cartagena, the demand is satisfied with water from Tagus-Segura interbasin transfer (122 hm^3/year), seawater desalination (26 hm^3/year), wastewater reuse (11.7 hm^3/year) and other local resources (Soto, 2020).

The intra-annual distribution of the water demand for irrigation (Soto, 2020) shows a peak in the summer, although more moderate than other irrigation schemes. Over 95% of the irrigation is done through drip irrigation systems.

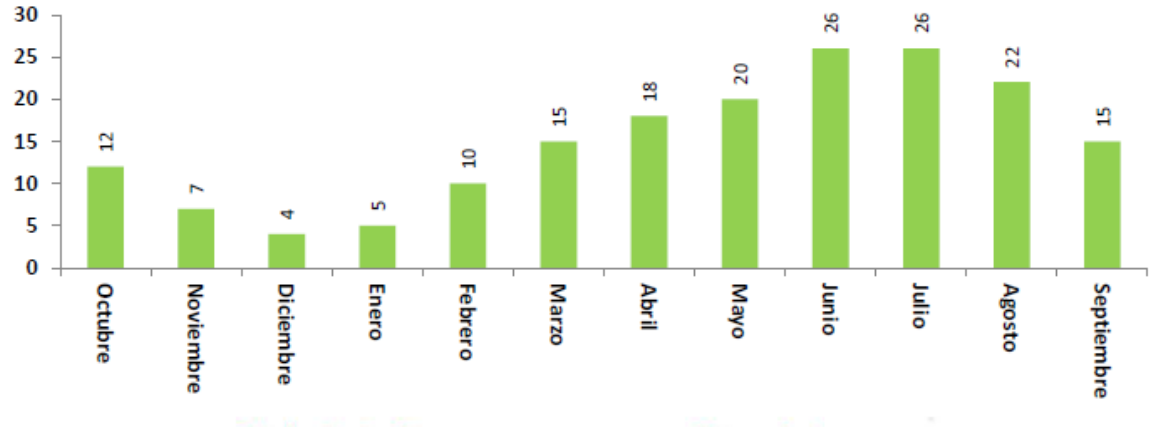


Figure 13. Irrigation piping network at Campo de Cartagena.
Source: Soto (2020)

The culture type is diversified in different fruits and vegetables (Figure 14).

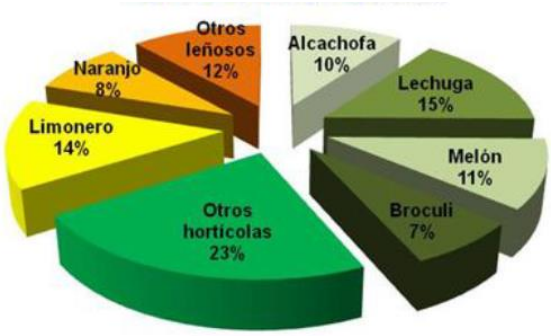


Figure 14. Culture type distribution.
Source: Soto (2020)

The area is fed by a main canal (64 km) from which pressurized pipes distribute the water (Figure 15).

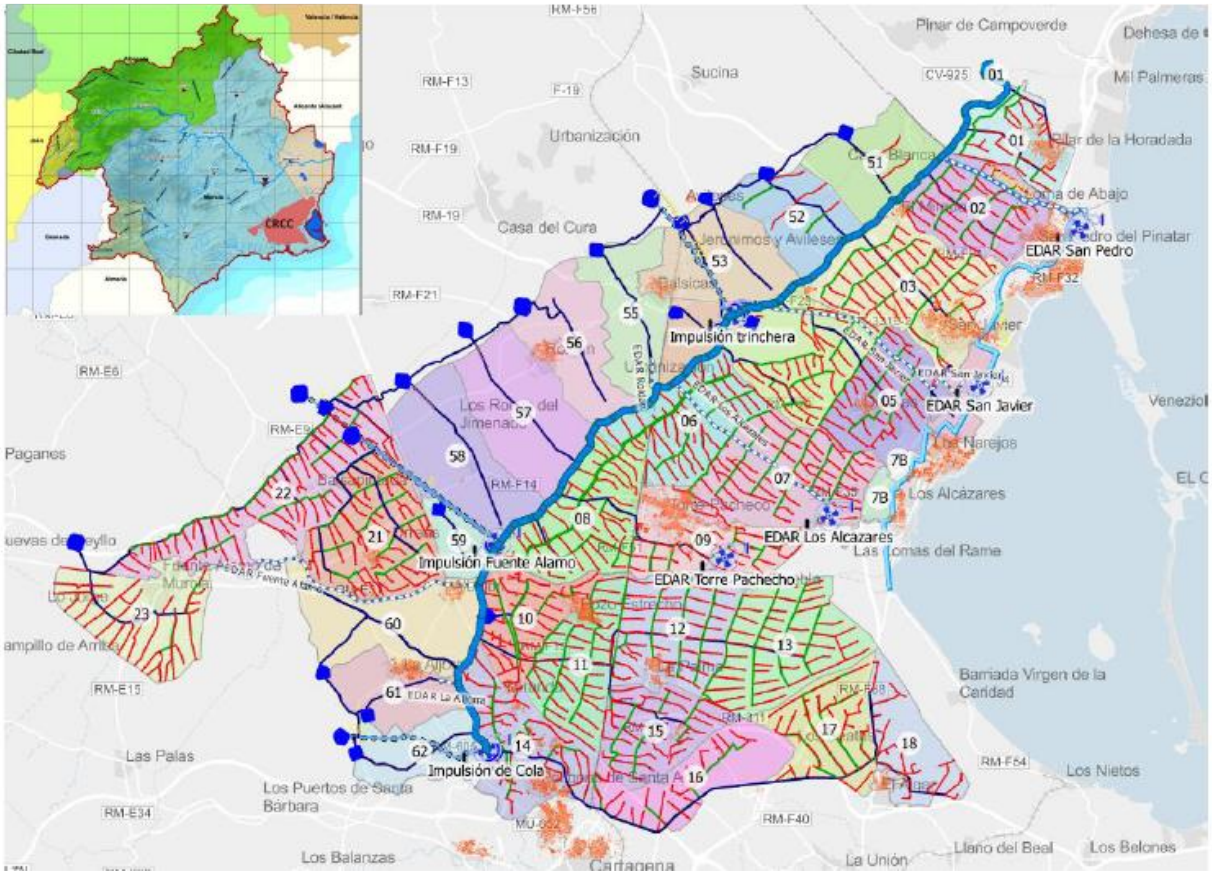


Figure 15. Irrigation piping network at Campo de Cartagena
Source: Soto (2020)

3.1. Surface water bodies in the Campo de Cartagena area

The only surface water body in the Campo de Cartagena area is Rambla de Albujón" (ES070MSPF001012801), categorized as ephemeral in Annex 12 of Segura River Management Plan. Confederación Hidrográfica del Segura (2016).

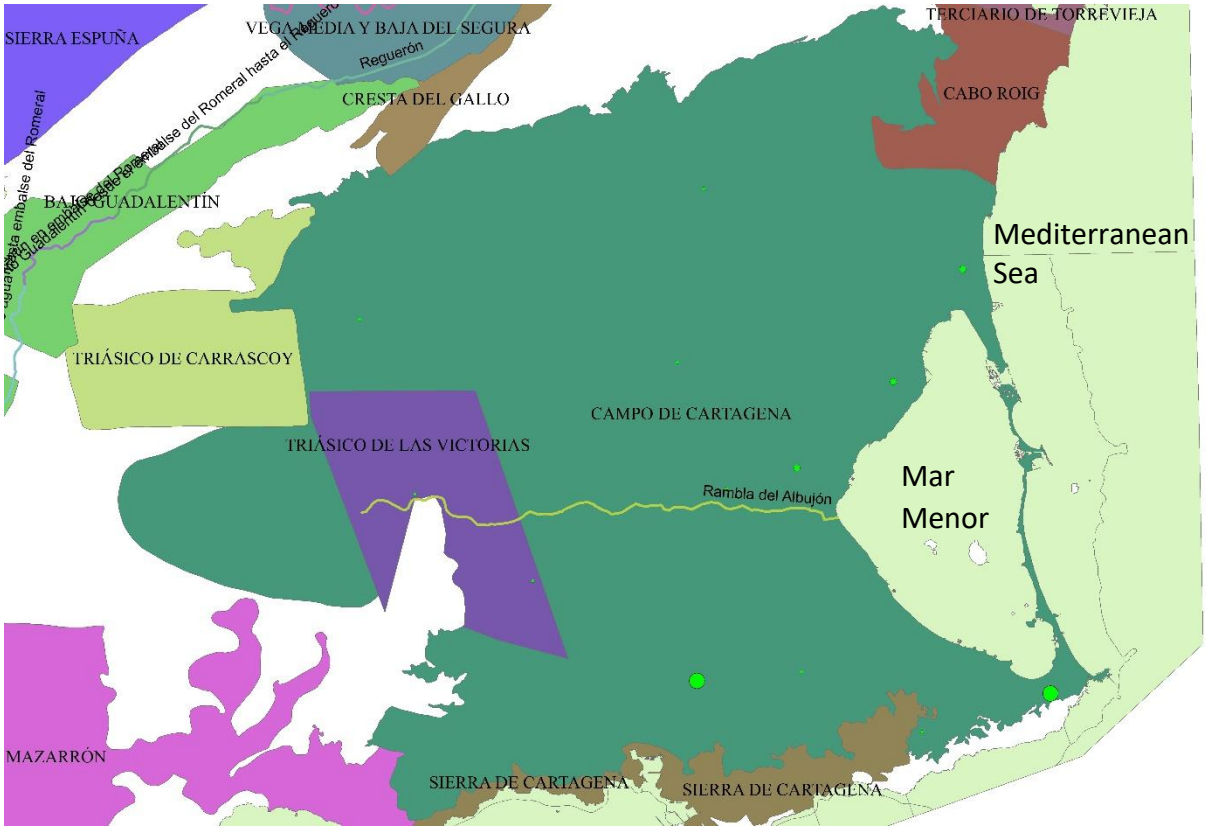


Figure 16. Surface and groundwater bodies in the Campo de Cartagena area.
Source: Confederación Hidrográfica del Segura (2016)

The water body is categorized as ecotype R-T13 "Ríos mediterráneos muy mineralizados", and has no Minimum Ecological Flow defined in the River Basin Management Plan (MAPAMA 2016, Appendix 6.1.2). Table 11 shows maximum concentration of pollutants allowed in the water body.

Table 11. Status change limits of R-T13 water bodies, according to RD817/2015

TIPOS RÍOS	INDICADOR	UNIDADES	CONDICIÓN DE REFERENCIA/ CONDICIÓN ESPECÍFICA DEL TIPO	LÍMITES DE CAMBIO DE CLASE DE ESTADO *Indicadores biológicos e hidromorfológicos: RCE* *Indicadores químicos: MEDIDA*			
				Muy bueno/ bueno	Bueno/ moderado	Moderado/ deficiente	Deficiente/ malo
R-T13	IBMWP	-	89	0,93	0,57	0,34	0,15
R-T13	IMMi-T	-	1	0,826	0,682	0,455	0,227
R-T13	IPS	-	17,7	1,00	0,75	0,50	0,25
R-T13	QBR	-	60	0,833			
R-T13	pH	-		6,5-8,7	6-9		
R-T13	Oxígeno	mg/L			5		
R-T13	% Oxígeno	%		70-100	60-120		
R-T13	Amonio	mg NH_4/L		0,2	0,6		
R-T13	Fosfatos	mg PO_4/L		0,4	0,5		
R-T13	Nitratos	mg NO_3/L		10	25		

Source: MAPAMA (2015)

According to the Segura River Basin Management Plan, the Rambla de Albujón water body appears as having a worse than good Ecological Status, and a good Chemical Status. The pressures behind the Ecological Status are declared to be point and diffuse nutrient pollution, and habitat alteration due to morphological changes. The river basin authorities consider that achieving the Good Status in 2015 would imply disproportionate costs and apply an exemption to reach the Good Status in 2027.

3.2. Groundwater bodies in the Campo de Cartagena area

The groundwater body "Campo de Cartagena" (ES070MSBT000000052 and 070.052) has an extension of 1238 km^2. With respect to its hydrogeology, the report in the Spanish Geological map (Instituto Geológico y Minero, 1993) states that:

"The aquifers exploited are the Pliocene sandstones and the Andalusian calcarenites and sandstones; in addition to the epirecifal facies that develop around the high Neogen (lithofacies that cause a high performance compared to the general trend of Campo de Cartagena). A third aquifer (Tortonian sandstones) could be investigated, taking into account the problems that its recharge and depth would present, in addition to the lateral change of facies that possibly exists towards the center of the basin ".

The Segura River Basin Authority gives the following definition to the groundbody:

"The limits of the mass are defined by the permothriasic and neogenic low permeability materials with which the formations of this unit come into contact laterally through tectonic accidents, with the exception of the eastern sector in which the limit is the Mediterranean Sea.

Within this mass, several aquifers have been differentiated (…), among which the following stand out due to their importance: Quaternary aquifer, made up of 20-150 m of gravel, sand, silt, clay and caliches deposited on tertiary marls that act as a waterproof base; Pliocene aquifer, formed by sandstones with varying thicknesses between 10 and 110 m, limited at the base and ceiling by marls from the Upper Miocene and Pliocene, respectively; Andalusian aquifer, made up of bioclastic limestones, sandstones and sands, with an average thickness of 125 m, limited at the base and roof by Tortonian and Andalusian marls. (…)

Given the complex internal tectonic structure of this depression, the discordant nature of many of its formations and the contact to the east with the Mar Menor and the Mediterranean, there is in certain areas a hydraulic connection between aquifers and between these and those seas.

The recharge of the Campo de Cartagena mass comes from the direct infiltration of rainwater and irrigation returns (largely concentrated in the Quaternary aquifer), although a possible lateral feeding from the Sierra de Cartagena should also be considered, although of little magnitude. The discharge is carried out by pumping (mainly in the Andalusian and Pliocene aquifers) and by lateral outlets towards the Mar Menor and the Mediterranean Sea (through the Quaternary aquifer). We must also take into account the internal interconnection between different aquifers, carried out under natural conditions and through poorly constructed boreholes, which has been estimated at an approximate annual average value of 40 hm3 (…). "

The “Campo de Cartagena” groundwater body is declared as having a poor Quantitative status in the Annex 8 of the River Basin Management Plan (Confederación Hidrográfica del Segura, 2016). Although the exploitation index is declared as Ie=1 in the Plan, meaning balanced water extractions with respect to the renewable resources, readings in the local piezometers (Figure 17) show a steady decrease of the water table level.

Cod. Piezómetro	07.31.099
Profundidad obra (m)	20
MASb controlada	CAMPO DE CARTAGENA
Provincia	Murcia
Municipio	Torre-Pacheco
Fecha Nivel	16-01-2002
Nº Medidas	145

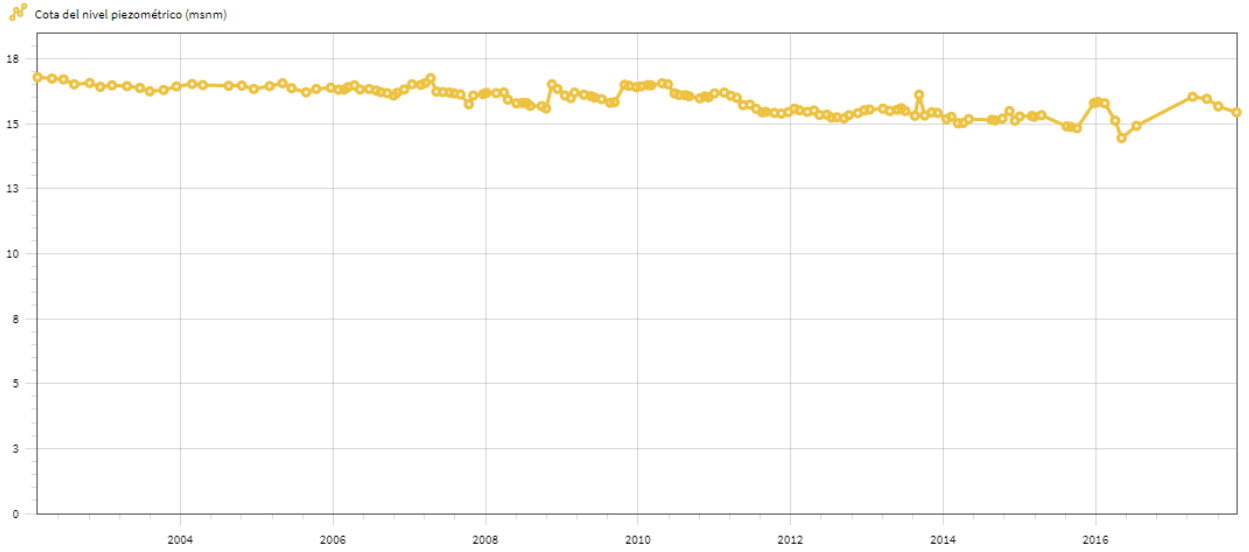


Figure 17. Water table level for piezometer 07.31.099 in groundwater body "Campo de Cartagena".
Source: Mitecord (2020)

The "Campo de Cartagena" groundwater body is also declared as having a poor Chemical status in the Annex 8 of the River Basin Management Plan (Confederación Hidrográfica del Segura, 2016). A less stringent environmental objective (according to article 4.5 of the WFD) has been declared due to quantitative and qualitative (nitrate concentration) problems. The less stringent goal is fixed as a concentration of 200 mg/l of nitrate in 2027. The River Basin Management Plan describes a generalized drawdown of the watertable and nutrient concentrations above limits (a breach of Lindane concentration is declared, but the plaguicide limit is declared as "complied"). The area is declared as vulnerable to nitrate pollution (Order of December 20th 2001, published by the Murcia Autonomous Community Official Bulletin in December 31st 2001). Also, the Resolution of March 24th 2001 of the Environment Ministry declares some zones in the Campo de Cartagena as vulnerable.

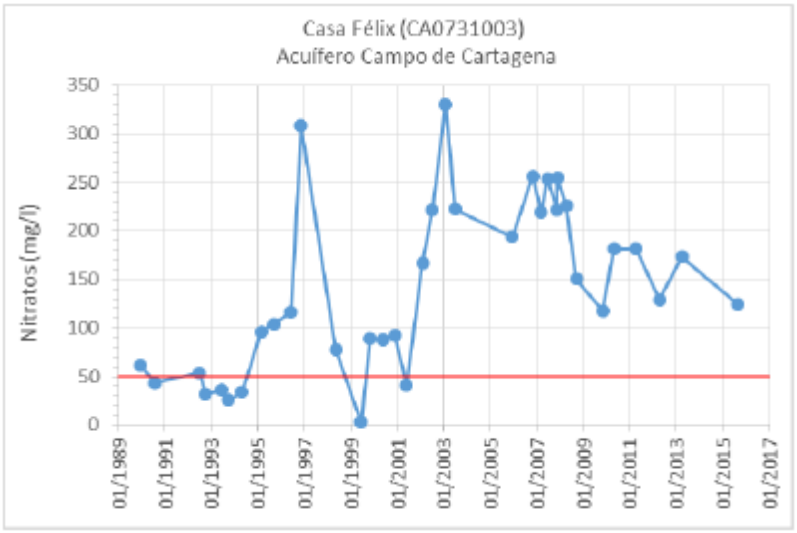


Figure 18. Nitrate concentration at borehole CA0731003 in groundwater body "Campo de Cartagena".
Source: Comunidad de Regantes del Campo de Cartagena (2017)

3.1. WWTP in the Campo de Cartagena area.

The treated wastewater of several WWTPs (**¡Error! No se encuentra el origen de la referencia.** and Figure 19) is recycled to reuse standards for irrigation.

Table 12. Authorized reuse volumes of WWTP at Campo de Cartagena

WWTP	*hm3/year*
Fuente Alamo	0,654
Torre Pacheco	1,825
San Javier	2,894
Balsicas- Roldán	1,000
Los Alcázares	2,611
La Aljorra	0,270
San Pedro del Pinatar	2,430

Source: Soto (2020)

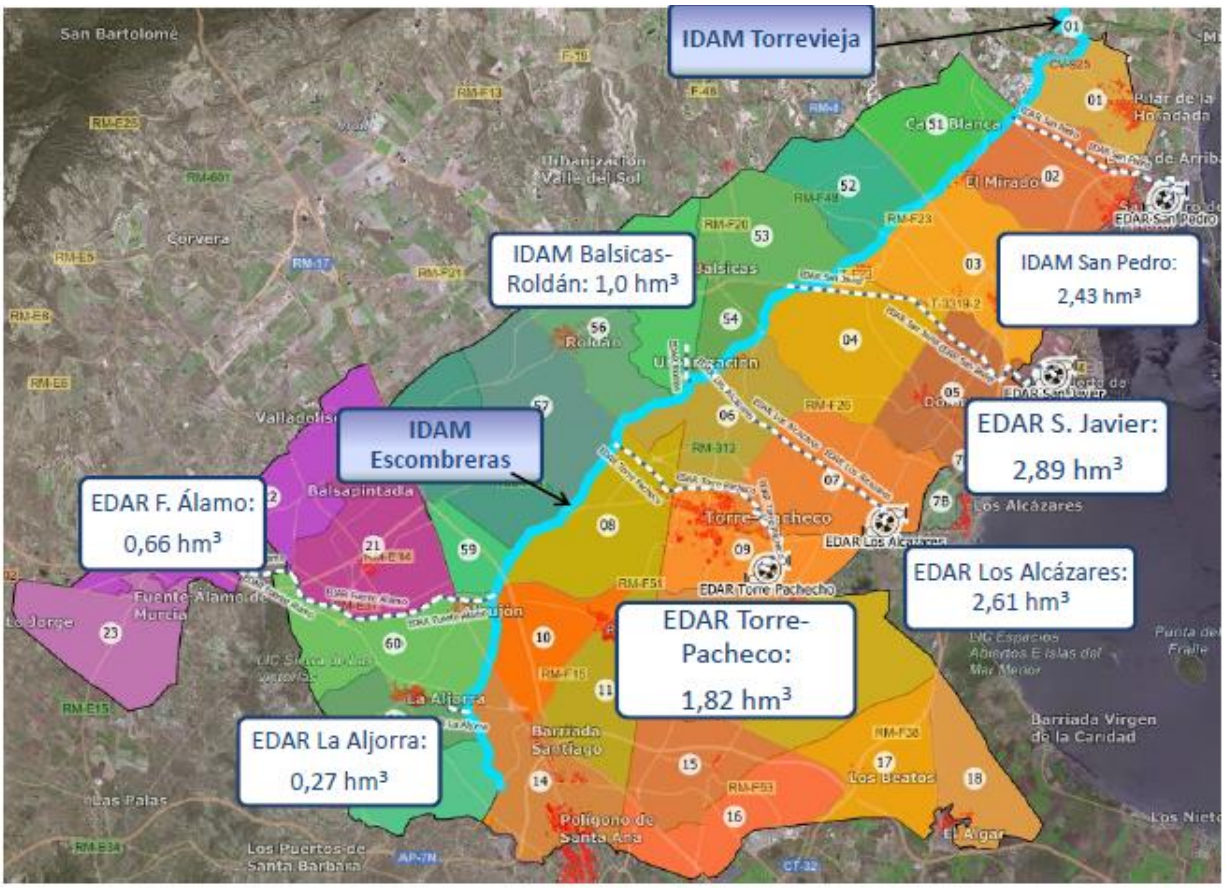


Figure 19. WWTPs at Campo de Cartagena
Note: EDAR = WWTP, IDAM = Desalinization Plant). Different colors represent different Agrarian Demand Units.
Source: Soto (2020)

For example, Torre Pacheco WWTP (uwwCode ES143003700130l0E) has a load of 24'152 p-e and a capacity of 81'000 p-e, and is located in the central part of Campo de Cartagena. The WWTP process consists of a pretreatment and an extended areation activated sludge reactor with a nitrification-denitrification cycle. The Water Reuse Plant has a process of coagulation-floculation, lamelar settling, sand bed filtration, Ultraviolet desinfaction and a complementary residual chlorine disinfection (Ródenas, 2010).

For the WWTPs located in the catchment area of Mar Menor, the Resolution of February 6th, 2019 applies restrictions to Phosphorus emissions.

Table 13. Except of Resolution of February 6th, 2019 of zones sensitive to euthrophication in the Segura River Basin.

Descripción de la zona sensible						Aglomeraciones urbanas mayores de 10.000 habitantes equivalentes		
Código	Nombre	Masa de agua	Criterio de designación	Fecha de la declaración	Zona de captación	Nombre	Código	Comunidad Autónoma
ESLK655	El Hondo de Elche-Crevillente.	ES070MSPF002100001	aP	30/06/1998	ESCM655	Crevillent I.	ES10030590002021	Com. Valenciana.
						Crevillent II.	ES10030590002022	
ESLK762	Lagunas de Torrevieja y La Mata.	ES070MSPF002120001	aP	30/06/1998	ESCM762	–	–	Com. Valenciana.
ESLK837	Embalse de Anchuricas (Cazorla II).	ES070MSPF002050102	aP	30/06/1998	ESCM837	–	–	Andalucía.
ESRI1032	Rambla del Albujón.	ES070MSPF001012801	aP	30/06/2011	ESCM1032	Torrepacheco.	ES14300370013010	Murcia.
						Fuente Álamo.	ES14300210902010	
ESRI501	Embalse de Camarillas.	ES070MSPF002050305	aP	28/07/2006	ESCM501	Hellín.	ES8020370005010	Castilla-La Macha. Murcia.
						Tobarra.	ES8020740006010	
ESRI589	Embalse de Argos.	ES070MSPF002051902	aP	30/06/1998	ESCM589	Caravaca de la Cruz.	ES14300150004010	Murcia.
						Cehegín.	ES14300170008010	
ESCA627*	Mar Menor.	ES070MSPF010300050	aP	23/06/2001	ESCM627	La Unión.	ES14300410305010	Murcia.
						Roldán-Lo Ferro-Balsicas.	ES14300370002011	
						Los Alcázares.	ES14309020001010	

Source: Ministerio para la Transición Ecológica (2019)

3.1. Water reuse in the Campo de Cartagena area

In the case of Segura River Basin, section 2.6.2.2 of the River Basin Management Plan (Confederación Hidrográfica del Segura, 2016) declares a treatment to reuse standards of 140.1 hm^3/year. 78.2 hm^3/year were directly reused, while the rest was discharged to surface waters and mostly reused downstream. The policy of the River Basin Authority has been to implement reuse capabilities to all WWTP with a discharged volume above 250'000 m3/year. Figure 20 shows how the biggest share of this volume has been destined to agricultural uses, while a small percentage has been used for golf course irrigation or for environmental purposes (river flow increase).

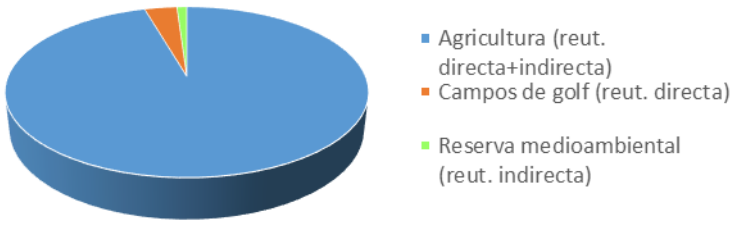


Figure 20. Destination of reused water at Segura river basin
Source: MITECO (2019)

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