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Article

Proposal of the "Wastewater Use Basin" Concept as an Integrated Sewage and Rainwater Management Unit in Semiarid Regions—A Case Study in the Southeast of the Iberian Peninsula

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Abstract: Semi-arid and arid regions are characterized by their water scarcity, which leads territories to seek ways of increasing the water resources available to meet their demands (urban, agricultural, industrial, leisure and tourism, etc.). For this reason, this article proposes the term "wastewater use basin"; the concept of the "wastewater use basin" is presented as a working unit of a smaller scale than traditional river basins, which allows for a better management of the water collected in the sewerage network and rainwater of urban agglomerations. It is a geographically-focused proposal for the integrated management of wastewater and stormwater that ends up in a wastewater treatment plant for treatment and reuse. The study area is located in the southeast of the Iberian Peninsula, Spain; specifically, the Campo of Cartagena-Mar Menor district (Murcia) and Vega Baja district (Alicante). The results show the trend behaviour of rainfall in the Segura river basin in recent episodes of torrential rainfall. There is a clear tendency for these episodes to occur in the coastal and pre-coastal areas, so that the water does not reach the headwaters where the reservoirs are located. For this reason, the proposed concept includes the area of the basin that would be formed by the wastewater and rainwater collectors which, in short, are intended to be treated in a treatment plant for subsequent reuse. The calculations made on the basis of the capacity of the environmental tanks executed and projected amount to four cubic hectometers which could be added to the hydrological planning of the Segura basin. In conclusion, the collection of rainwater allows the incorporation of an additional volume of water that complements and increases the resources offered by the treatment plants in the hydrological planning. It also serves as a measure of adaptation to climatic extremes (droughts and floods) and to the effects of climate change, supporting a circular management of the use of resources.

Keywords: sewage; rainwater; environmental tanks; climate change; drought

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1. Introduction

The effect of climate change in arid and semi-arid regions already shows a notable decrease in water resources in river basins [1–3]. This evidences the need to rethink hydrological planning due to the constant pressure on resources for different uses—economic, environmental, patrimonial—due to their projected decreasing trend [4]. In semi-arid areas, the traditional paradigm of hydrological planning—predominantly based on conventional resource supply policies—must be modified. Efforts must be directed towards a "sustainable" hydrological planning in which the territories seek water self-supply through the use of water resources of diverse origin (conventional and non-conventional), thus trying to reduce dependence on other hydrographic basins—transfers of water [5]—and frequent atmospheric conjunctures—droughts [6]. In the current context of climate change, one of the main ways of obtaining water resources that are not subjected to climatic variations is by increasing the so-called non-conventional sources, particularly the use of treated sewage and desalinated water [5]. Collection of rainwater in large-capacity tanks and its use can also be considered [7], which makes it possible to take advantage of the intense rainfall that has occurred frequently, in recent decades, in some climatic regions such as the Mediterranean [8].

Generally, the main idea of the current legislation on the regulation of discharges from point sources laid down in legal norms is to determine the maximum permissible concentration/loads of pollutants in wastewater discharged into the receiver to ensure good water quality of the water body [9]. The approval of Directive 60/2000/EC, which establishes a community action framework in the field of water policy (also named Water Framework Directive, WFD), made clear its purpose to prevent further deterioration, protect and improve the state of aquatic ecosystems, promote the sustainable use of water based on long-term protection of available water resources, and mitigate the effects of floods and droughts, while seeking to guarantee a sufficient supply of surface and groundwater, through sustainable, balanced and equitable use, among others.

However, the new reality of hydrological planning, conditioned by the effects of climate change [5], now allows the consideration of new possibilities in the water-resources planning protocol of the territories, especially in those with natural rainfall deficit and a scarcity of conventional sources (surface and groundwater). In this context, the territories can be adapted to the geographical area where resources are obtained to guarantee existing demands. This entails the complementarity between the general guidelines coming from the hydrographic demarcation area and the "spending units" on a regional or local scale, where resources can be obtained to guarantee the supply. In this way, greater efficiency can be achieved in hydrological planning by making the end user co-responsible for the management of water resources of territorial immediacy [10].

Planning in units smaller than the hydrographic demarcation must include the incorporation, along with conventional resources, of "unconventional" resources coming from sewage treatment, rainwater from the development of catchment systems and, if necessary, covering important deficits (structural or short-term droughts), from desalination.

WFD (60/2000/CE) mentions sewage treatment as a service related to water, the collection and purification of wastewater, which is later discharged into surface water. In order to allow this, it promotes the installation of a sewage treatment plant (STP) to determine the emission limit values (discharge), guaranteeing an equivalent level of protection for the environment as a whole, not causing higher levels of contamination.

Managing wastewater is indeed one of the Sustainable Development Goals within the 2030 UN Agenda. It tackles the long-term sustainability of the water system, which is questioned, for instance, in Switzerland [11], but more importantly, its interest contributed to a great development of research in multiple scopes. Its potential uses are widely studied, agriculture being the most common consumer, even to the extent that in Mexico, sewage creates socioeconomic dependence in the main urban agglomerations because of its application in agriculture [12]. However, sometimes, even if it is not widely allowed, there is a de facto reuse of these waters, which may be identified following the emissions of contaminants present in the treated wastewater [13]. For example, in the case of the US, Rice, Wutich and Westerhoff [14] found that, at 25 sites, the supply contained 2 to 16% reclaimed water discharged upstream. Leaving aside the benefits and disadvantages of the indirect or potable reuse [15] it has truly become a matter of social interest as it contributes to the water security in certain parts of the world, such as in Singapore [16], and it is frequently demanded that it should be considered when guaranteeing municipal supply [17]. Other studies previously examined the degree of removal of certain pollutants, such as in France or the Netherlands, in order to help the optimization of the process [18,19].

However, although wastewater, its uses and mechanisms of control are widely studied, the vision of managing wastewater in a territorial concept is often lacking; thus, this article intends to shed light on this issue proposing an organization of the wastewater use basin.

In Spain, purification was not part of hydrological planning until 2004 with the approval of Royal Decree Law 2/2004, which modifies the National Hydrological Plan of Spain, repealing the transfer project from the Ebro Basin to the Júcar, Segura and South basins. In this context, for the first time in the hydrological planning of the basins, the water resources of the treatment plants and desalination plants were included as water resources aimed at supplying the agricultural, urban, tourist and environmental demands of the Spanish hydrographic demarcations.

The recently approved Law 7/2021 on climate change and energy transition deals with the consideration of climate change in the planning and management of water, whose objective is to achieve water security for people, the protection of biodiversity and socioeconomic activities, in accordance with the hierarchy of uses, reducing exposure and vulnerability to climate change and increasing resilience.

Therefore, it is proposed that hydrological planning and management should anticipate the foreseeable impacts of climate change, identify and manage risks derived from climate change in relation to its impact on crops and agronomic needs, and plan for the impacts derived from climate change in water resources, and the adaptation of the uses of water that are compatible with the available resources, among others.

The climate change models evidence the reduction in water resources in river basins, associated with the scenarios of reduced rainfall in the headwaters of the river basins [20–22], and, for its part, an increase in the volume of reused water from the STPs and an increase in the volume of desalinated water [5].

Within water supply management, it is worth noting the role that purification has been gaining in this geographical space, as it has recently emerged as a resource that allows water security to be achieved [23–25], in a context where political-territorial tensions and the effects of climate change have complicated inter-basin water transfers [26,27]. Water recycling is a resource that is used almost entirely, agriculture being the most common use [28].

Sewage management involves managing the territory from an integrated point of view. Its interest lies not only in the purification of pathogenic agents and pollutants for the environment, which represents its environmental value, but also constitutes a water resource for the water mix: currently, the uses of this recycled or regenerated water can be agriculture [29], leisure sports, other urban uses or to serve as environmental flows. However, potable reuse is a fact in many areas of the world, such as Singapore, California, Namibia and Australia [30,31].

In the European Union, potable reuse is not allowed, in addition to this being classified as the least accepted water resource by society [31]. Its advantages lie in the lower cost compared to desalination [32], the relief of competition for water uses, the reduction in overexploitation of aquifers and, above all, the certainty of flows, which are determined by the drainage of runoff after the rains and the consumption of drinking water. For this reason, potable reuse, both indirect (IPR) and direct (DPR), constitutes one of the most sustainable strategies practiced in regions with a scarcity of water resources. It should be borne in mind that, on the Mediterranean coast, the seasonality of drinking water consumption is elevated and, furthermore, the greatest influx of tourists coincides with the characteristic summer drought [33].

In some territories, rainwater from episodes of intense rain has joined the resources coming from the purification of urban sewage, after being collected in tanks and subsequently directed to the treatment plants to proceed to its regeneration, prior to its reuse. In this way, the scheme of a circular water economy that takes advantage of the "unconventional" resources that occur in a residual basin is closed.

The process of connecting rainwater and sewage has been developed in recent decades in the territory of the southeast of the Iberian Peninsula. At a first stage, the construction of infrastructures (tanks and floodplain parks) takes place to reduce the damage caused by intense precipitation events and, later, the connection with the STPs is developed to incorporate these resources into the water mix.

The collection of rainwater acquires a special meaning in urban environments, both for the prevention of floods and the collapse of infrastructures and for representing flows with a high concentration of polluting elements for the receiving environment. These effects may be mitigated through proper planning, which includes the construction of environmental tanks, regulation infrastructures and subsequent treatment in STPs. This alternative technique makes it possible to achieve water security and sustainability, in other words, a commitment to self-sufficiency with its own resources. It is an example of a local and freely accessible resource with minimal energy costs.

The so-called Combined Sewer Overflows (CSOs) are one of the main sources of contamination of the receiving environment, and in order to reduce this contamination, storm tanks are built. According to Barro et al. [34], a storm tank or deposit can be defined as a hydraulic-sanitary infrastructure designed to optimize the management of the flows of the unitary systems in rainy weather through regulation and treatment strategies of these flows. These regulation and treatment infrastructures could also be called anti-overflow of unitary systems. The name environmental tanks refers to these infrastructures, which fulfill an environmental task: they prevent the first runoff, which is the most polluted as the rain washes out the asphalt, from being discharged directly into natural aquatic systems, such as the Mar Menor lagoon, and are subsequently conducted to STPs where, once the water has been decontaminated, it can be used.

Such is the growing importance of rainwater collection for domestic use that, in Sydney, it is necessary for new buildings to be able to save 40% of water by collecting water from the roof for its use in toilets and gardens as part of the requirements of the Building Sustainability Index [35]. In Spain, there are several examples of rainwater harvesting through the existence of storage devices (environmental tanks, laminating ponds, floodplain parks, etc.). In the Barcelona Metropolitan Area, the Special Sewerage Plan and the Stormwater Master Plan were finalized within the scope of the EMSHTR (Metropolitan Entity for Hydraulic Services and Waste Treatment), and other studies by the Consortium for the Protection of the Besòs River Basin. Among the environmental tanks built, with the aim of reducing the impact of CSOs, the Taulat tank in Barcelona (50,000 m^3) and the Estrella tank in Badalona (30,000 m^3) stood out. Concern and commitment in this matter lead to abundant examples: in Asturias there are 354 tanks, Santander Bay has 5, and the city of Madrid has 28 of them with a global volume of 1,300,000 m^3.

In Alicante there are also 2 paradigmatic examples: (a) the storm tank named José Manuel Obrero with a capacity of 60,000 m^3, and (b) the flood park called “La Marjal” with a capacity of 45,000 m^3 [7,36–39] collect rainwater from the rainwater network, store it and then send it to sewage treatment plants for treatment and reuse for agricultural or urban uses. It must be noted that these large deposits alleviate peak flows, and avoid floods and the harmful impacts on social, economic and environmental systems [40].

Sewage management is part of the circular economy paradigm. This is an essential piece of the European Union’s climate change mitigation strategy: water is a fundamental element of the European Green Pact 2019–2024 [41]. Likewise, the United Nations Sustainable Development Goals converge on the need to make comprehensive use of water resources and extend water security and sustainability to society as a whole. The objective is the total reuse of sewage once it has received advanced tertiary treatment to eliminate pathogens. Bearing in mind all the costs of production, extraction and transport, desalination is the most expensive option compared to the other sources (stormwater and IPR) [32]. Nonetheless, it depends on the decisionmakers and the final use of the water, as Diogo, Resende, and Oliveira [42] show in the case of Cape Verde, where the most suitable source for landscape irrigation was freshwater and reclaimed water, while for water distribution it was groundwater and desalinated water. In the area of study, due to the marine intrusion into the sewerage system, STPs’ effluent must be treated once more with reverse osmosis, in order to adjust the salinity levels. Thus, the protection of the system is a keystone to reduce the energy consumed and avoid these additional procedures. Climate change forecasts and competition for water uses in regions with water scarcity make it urgent and a priority to deepen sewage management.

In the Spanish territory there is a particularly suitable geographical space to analyze the feasibility of wastewater use basins considering their climatic conditions (semi-arid climate) and the current reality of their hydrological planning model (supply model), as well as the possibility of using non-conventional water from different sources (recycled water, rainwater and desalinated).

This paper raises the need to move from a water planning model based on the continuous supply of the resource (surface water, groundwater and transfers between basins) to another, adapted to the current conditions of reduced rainfall in the context of climate change. Therefore, the objectives are:

1. Highlight the importance and applicability of the concept of the "wastewater use basin" and its application in semi-arid and arid areas such as Campo of Cartagena–Mar Menor (Murcia) and Vega Baja (Alicante) in Spain, as a possibility of increasing water resources in deficit areas.
2. Promote the implementation of the "wastewater use basin" concept to incorporate it into hydrological planning in the context of transposition of the new European regulation 741/2020 that comes into force in 2023.
3. Promote the construction of environmental tanks that capture rainwater as an additional resource to the STPs.
4. Support a sustainable hydrological planning where reclaimed water (purified + rainwater) is used directly and indirectly.

In short, the aim is to analyze a new reality in the planning and management of water in areas with structural scarcity of resources due to their semi-arid climatic features, in a complex context such as climate change with high future uncertainty.

2. Materials and Methods

2.1. Study Area

The study area is located in the southeast of Spain and covers two regions: Campo of Cartagena–Mar Menor (Region of Murcia) and Vega Baja (Valencian Community) (Figure 1), both semi-arid regions.

This climate is characterized by mild temperatures in winter and high temperatures in the summer months. In relation to rainfall, the average total annual rainfall in this territory ranges between 150 and 300 mm per year (Figure 2), and is characterized by being irregular and torrential, especially that which comes from the Mediterranean.

This type of rain is usually concentrated in the first few kilometers of pre-coastal and coastal areas, which correspond to the lower course of rivers. This fact implies that the most voluminous precipitations cannot be used since the rains do not occur in the headwaters of the river basins that are regulated with numerous dams and reservoirs, for supply and agriculture. This makes it necessary to look for rainwater harvesting solutions in the lower course of the main streams.

According to this, the study area of this research refers to the Campo of Cartagena-Mar Menor district (Region of Murcia), made up of 7 municipalities and the southern part of the municipality of Murcia, which is geographically in this natural region; and the Vega Baja district (Alicante, Valencian Community), which brings together 27 municipalities. Both areas are part of the Segura Hydrographic Demarcation (DHS).

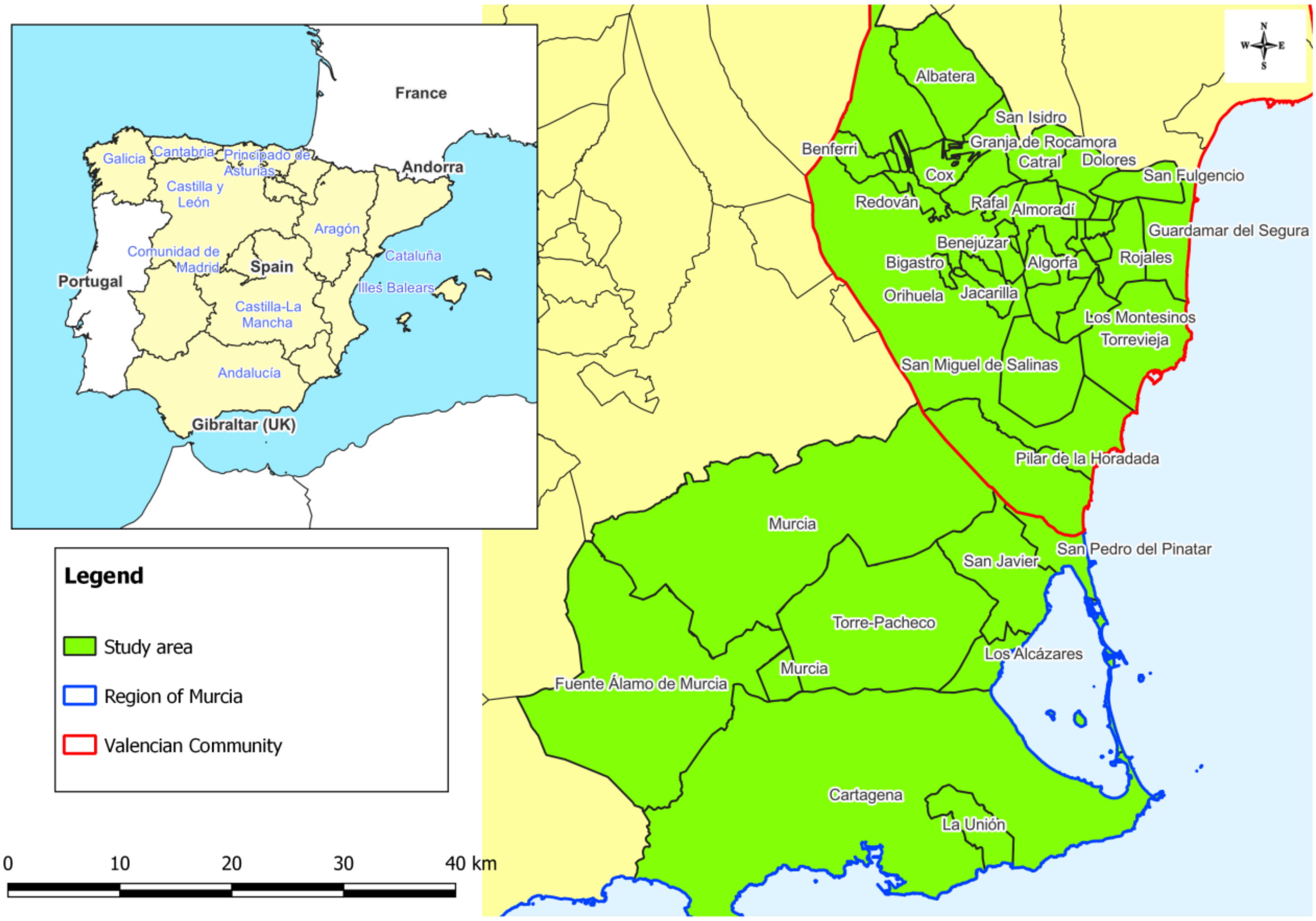

Figure 1. Study Area: Campo of Cartagena–Mar Menor (Region of Murcia) and Vega Baja (Valencian Community). Source: Valencian Cartographic Institute (ICV) and Nacional Geographic Institute (IGN). Own elaboration.

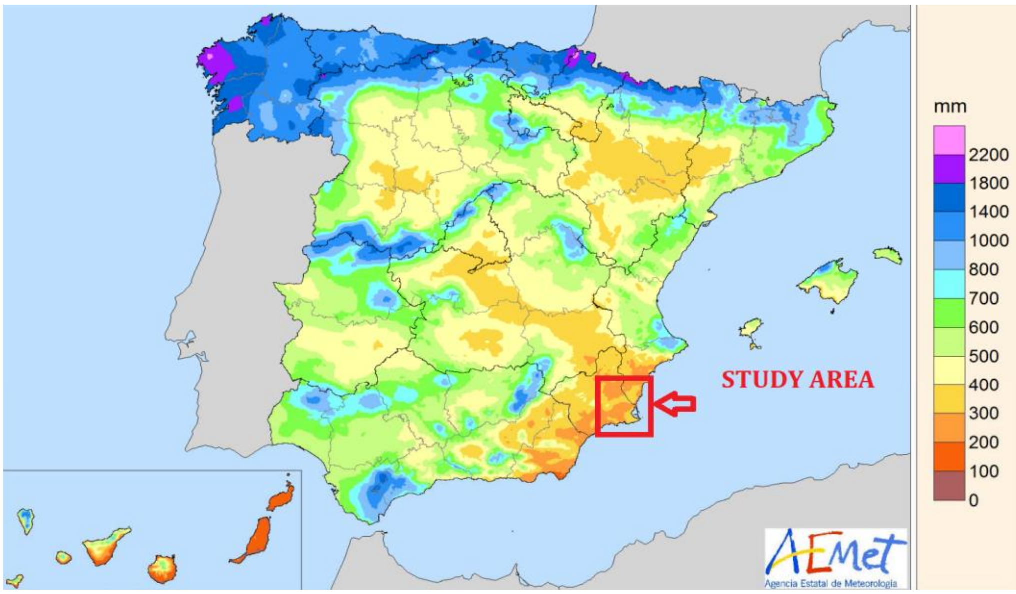

Figure 2. Average annual rainfall (1981–2010). Source: Climate Atlas of Spain (1981–2010). AEMET.

2.2. The Concept of the "Wastewater Use Basin"

Sewage and rainwater are of strategic importance in adapting to climate change and building resilient territories. Its management scope must be included within hydrological planning and within the scope of action in the traditional hydrographic basin [33], which is why the term "residual basin" or sewershed arises.

This is a concept of organization in the management of wastewater, defined by Bernabé-Crespo, Olcina and Lahora [15] as the entire area that discharges to the same STP, that is, the territory of action of a STP that is delimited due to its sewerage network, and collection and treatment infrastructure, which is equivalent to the delimitation of "urban agglomeration" as provided in Directive 91/271/EEC on urban wastewater treatment.

This paper proposes a new more comprehensive concept, the "wastewater use basin". The concept of the "wastewater use basin" is presented as a working unit on a smaller scale than traditional river basins, which allows for better management of the water collected in the sewerage network and rainwater. Both sewage and rainwater collected by the urban collectors have the ultimate aim of diverting the water to the nearest sewage treatment plant for specific treatment and, subsequently, reuse. The uses to which reclaimed water is put, regardless of its origin (sewage or rainwater), include agriculture, irrigation of parks and gardens, street cleaning, recreational uses, industrial uses and even, in some countries, as drinking water for human consumption.

It should be noted that sewage and stormwater circuits should, ideally, be different. Sewage flows from buildings and joins the urban sewerage network. These collectors direct all sewage to a specific sewerage collector that connects directly to the treatment plant so that its water can be treated on a daily basis. Rainwater, on the other hand, first circulates through the streets as runoff until it is incorporated into the rainwater network. The dragging of materials and pollutants means that the first rainwater that manages to "wash" the urban soil is the most polluting. For this reason, the networks of rainwater collectors usually divert their water to environmental reservoirs (storm tanks, flood parks, anti-DSU…) as storage devices during the rainy season. At the end of the rainfall event, the water is diverted from the storage devices to the collector of the sewerage network of the sewage treatment plant which, little by little, mixes the rainwater with the sewage to be treated as a whole.

In this way, both types of urban water end their journey by entering the nearest sewage treatment plant. For these reasons, both sewage and rainwater are considered to form part of the same basin, as their destination is the same treatment plant. Although their organic load and pollutants are thoroughly different, STPs must be able to treat these flows of water, which is being promoted by spreading the installation of tertiary treatment and ensuring that the effluent meets the criteria featured in the Directive 91/271 [15].

However, there are still many municipalities with a unitary and obsolete sewerage network. In this sense, both sewage and rainwater circulate in the same collectors, which means that in episodes of heavy or torrential rainfall their hydraulic capacities are often exceeded. This type of network mixes sewage and rainwater, and they end up being incorporated into the sewerage network of the treatment plant, and treated simultaneously. This is the case in most of the municipalities in these study areas. Separate sanitary sewer systems should be encouraged; not only do they reduce the hazards but also their cost-benefit approach is more profitable [43]. Mixed systems are beginning to be installed in the municipalities at present. In some cases, there are sectors in the same city with a unitary network and a mixed network. However, both are connected to the same sewerage collector that incorporates the water into the corresponding sewage treatment plant.

For these reasons, the concept of the "wastewater use basin" is justified as a proposal for sewage and stormwater management in catchment areas.

The concept of the wastewater use basin includes, therefore, the flows of sewage, stormwater and the management of floods, since depending on the runoff in that basin, the capacity of the STP will be planned, the types of treatment, and where to locate the deposits (including environmental tanks) in anticipation of torrential precipitation events (Figure 3).

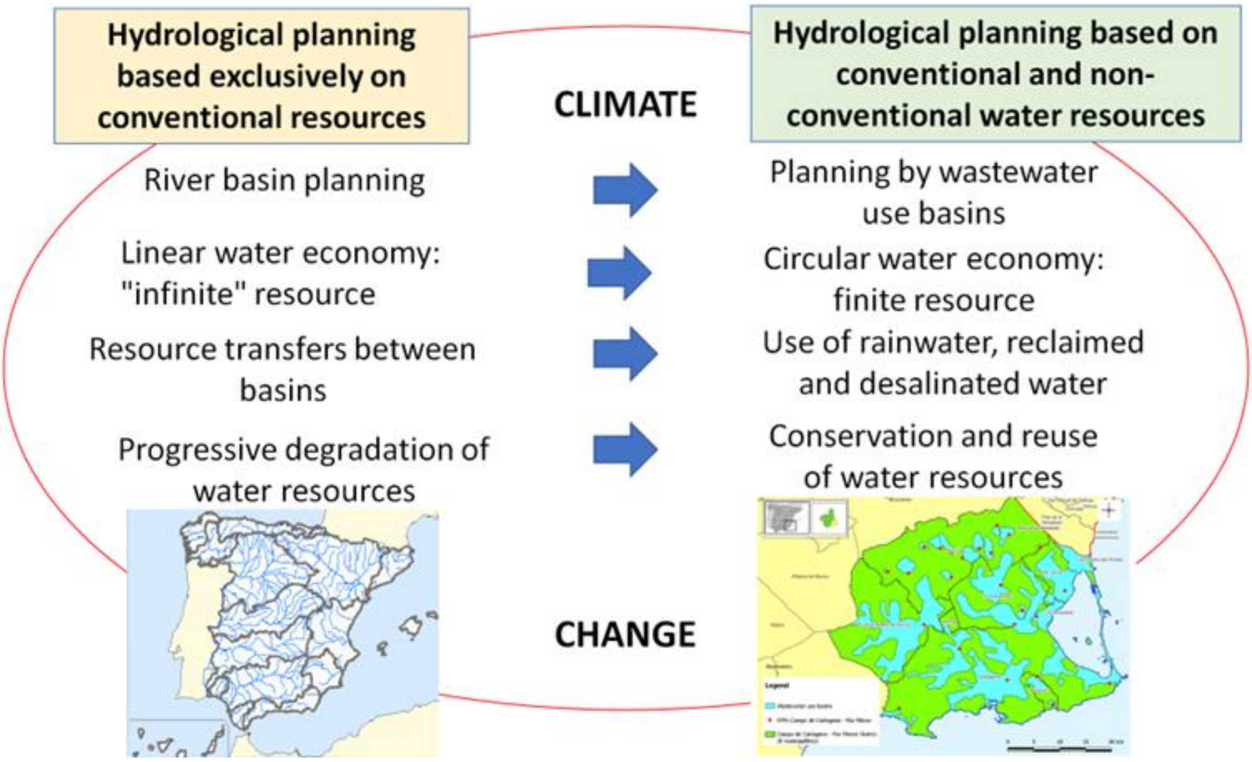

Figure 3. Conceptual framework of the wastewater use basin. Source: Own elaboration.

A wastewater use basin would be the territory comprised by the area of influence of a STP that can treat both urban/industrial wastewater and rainwater collected in environmental tanks (rainfall tanks and floodplains) and also treated by a STP. These purification stations can also incorporate desalination systems (reverse osmosis) in the treatment process to improve the quality of the final product.

2.3. Data

At this point, it is appropriate to clarify the definitions of purified water and reclaimed water to understand the situation in which the treatment plants in the study area are located. On the one hand, purified waters are those that have received certain treatments to comply with discharge regulations, so that they do not contaminate or affect the nearest aquatic and natural ecosystems. This treatment is required by different regulations, both European and national. On the other hand, reclaimed waters are those that have received treatment in addition to purification; therefore, they are cleaner waters and can be directly reused for various urban and agricultural uses (washing streets, ornamental fountains, irrigation of parks and gardens, roundabouts, golf courses, and direct or indirect irrigation for crops, depending on the quality allowed by European and national regulations.

For the purpose of this research, it was necessary to request the information from the entities in charge of sewage treatment in both regions. These entities are the Regional Sanitation and Purification Entity of the Region of Murcia (ESAMUR, hereinafter) and the Public Wastewater Sanitation Entity of the Valencian Community (EPSAR, hereinafter).

The information provided by the sanitation entities is the location of the STPs and the sections of collectors that collect both residual and rainwater and that are connected to the sewage system of urban areas. In the case of Murcia, ESAMUR provided the data which made it possible to draw up the cartography referring to the territorial scope of each STP, through the delimitation of "urban agglomerations" as provided in Directive 91/271/CEE on the treatment of urban sewage, which is equivalent to the territory connected to a STP. In the case of the Vega Baja district, the Provincial Council of Alicante has a cartographic viewer that allows the activation of a series of thematic areas (supply, equipment, road network, waste, sanitation, services. . .), which made possible the development of the results referring to the residual basins of the Vega Baja district (http://eiel.diputacionalicante.es/Default.aspx, (accessed on 14 May 2023)).

With regard to the environmental tanks, the General Directorate of Water, dependent on the Regional Office of Water, Agriculture, Livestock, Fisheries and the Environment of the Autonomous Community of the Region of Murcia, provided information on the different environmental tanks present in this province. In the case of Vega Baja district, this information was requested from the Plan Vega Renhace and the Regional Office of Territorial Policy, Public Works and Mobility of the Generalitat Valenciana (autonomous government), extracted from the Master Plan of Sustainable Urban Drainage Systems of the Vega Baja district. In this document, different municipalities' proposals are listed. Most of them have some action related to the construction of some type of storage device (environmental tanks, flood parks, laminating ponds . . .) for the collection of rainwater, through a system of rainwater collectors.

2.4. Preparation of "Wastewater Use Basin" Maps and Location of Environmental Tanks

For the elaboration of the maps shown, a Geographic Information System (GIS) has been used, in this case GvSIG and QGIS (version 3.26.2, Buenos Aires). The layers for the location map were obtained from the Download Center of the National Geographic Information Center (CNIG) belonging to the National Geographic Institute (IGN) (http://centrodedescargas.cnig.es/CentroDescargas/index.jsp, accessed on 23 April 2023), the database of Murcia, and through the Valencian Spatial Data Infrastructure (IDEV) of the Valencian Cartographic Institute (ICV) (https://idev.gva.es/va/inicio, (accessed on 23 April 2023)). Thanks to the data provided by the sanitation entities, it was possible to geolocate the location of the STPs in the study area, as well as to identify the collector that gathers the sewage and rainwater, redirecting them to the STPs.

As mentioned above, the first step in the methodology was to geolocate the location of the wastewater treatment plants in the study area. Each wastewater treatment plant comes with reference geographic coordinates that were transformed into UTM 30 N coordinates with an EPSG 25830 projection as required by European regulations.

This information was created in an excel document which was then saved as a CSV file (comma delimited). This file was included in the mapping programs using the UTM coordinates. The result was the location (in points) of the wastewater treatment plants in the study area.

Subsequently, using the information provided by Murcia and the viewer of the Diputación de Alicante, a new polygonal layer was created to delimit the work unit that has been called the "wastewater use basin" in this article.

The delimitation of this area was based on knowing the existing sewerage network in the municipalities that make up the study area, and its connection to the nearest wastewater treatment plant or plants.

In the case of the study area, the preparation has been simpler because most of the municipalities still have an obsolete unitary network (wastewater and rainwater), although they are beginning to implement the mixed system.

Therefore, the steps to be followed for the elaboration have been: (1) to locate the location of the wastewater treatment plant (A); (2) the location of the sewerage collector that connects the urban sewer with the wastewater treatment plant (B); (3) to know the totality of the existing urban wastewater collectors (C); and (4) to delimit the area of influence (D) (Figure 4).

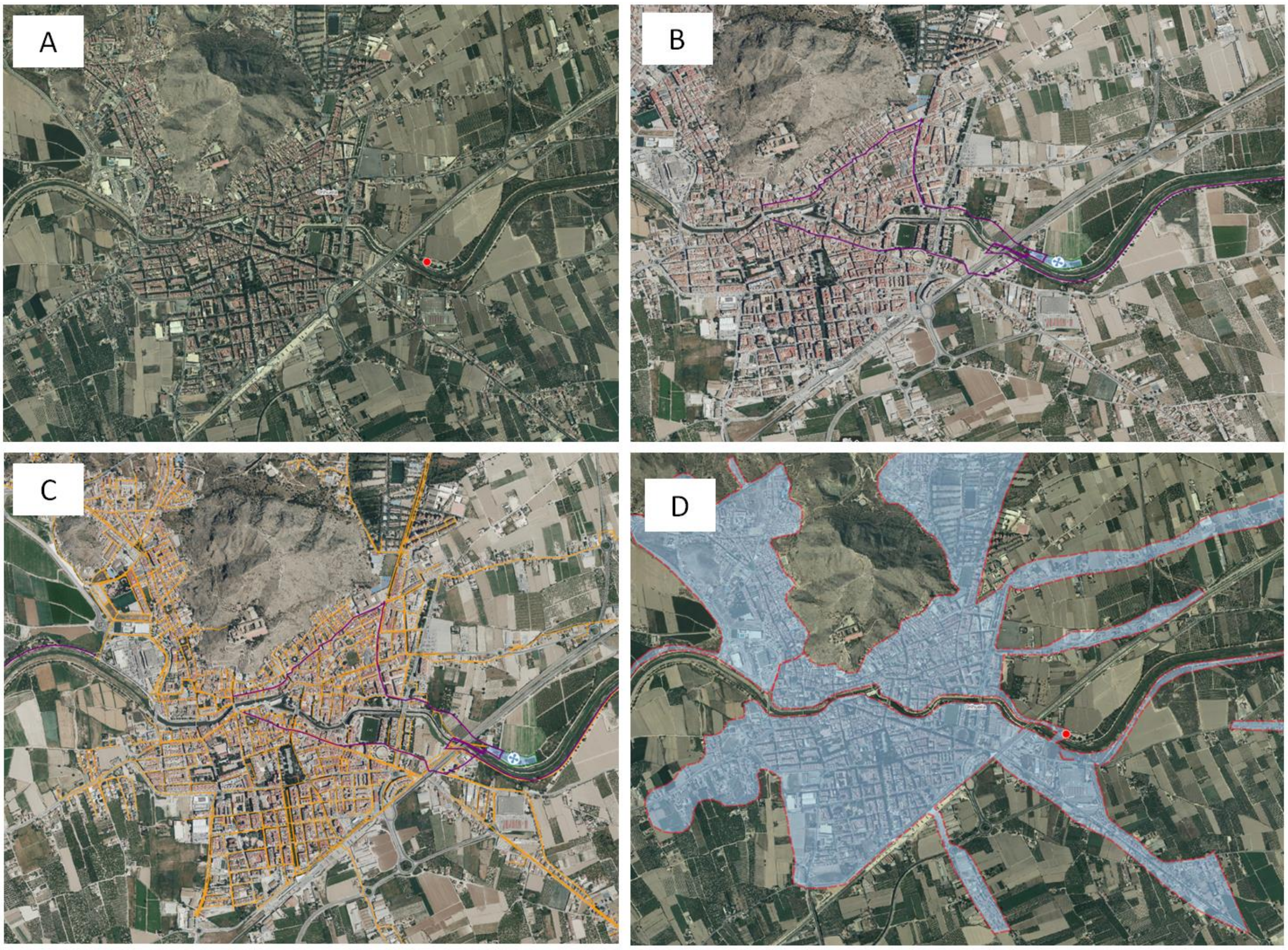

Figure 4. Methodology for wastewater use basin delimitation: Example in the city of Orihuela. Source: The image (**A**) shows a red dot where the Orihuela wastewater treatment plant is located. In the image (**B**) you can see purple lines representing the wastewater collectors that collect the wastewater from the sewage system of the town and its connection to the sewage treatment plant. In the image (**C**) you can see the municipal collectors (orange lines) connecting with the collectors of the sewerage network (purple lines) which connect to the Orihuela wastewater treatment plant (red dot). Image (**D**) shows the result of the methodological proposal mapping the surface of the existing sewerage network in Orihuela connected to the wastewater treatment plant. Diputación of Alicante. Own elaboration.

The procedure for delimiting stormwater is the same, except for a small variation: (1) locate the location of the treatment plant (A); (2) the location of the sewerage collector that connects to the stormwater storage devices (environmental tanks) (B) or (Figure 5); (3) know the totality of the stormwater collectors that connect to the storage devices (C); and (4) delimit the area of influence (D).

Figure 5. Methodology for wastewater use basin delimitation: Example Flood Park "El Recorral" (Rojales). Source: Diputación de Alicante. Own elaboration.

It is worth recalling that STPs form the end point of the residual basin, so the rest of the "channels" of the aforementioned basin refer to the sewage collectors and rainwater that circulates superficially through the urban environment until its connection to the system through the sewerage network. This usually happens in unitary sewerage networks (residual and stormwater in the same collector). On the other hand, there are also examples of mixed systems where the presence of a sewage network and another for rainwater are noted, where the latter is usually stored in environmental tanks that avoid contamination of the first rainwater, while serving as a storage device of rainwater until its subsequent treatment in STPs. As a result, the drainage network of the basin is composed of the sewage and stormwater systems. The area covered by this entire system, together with its end point (STP), shape the concept of the wastewater use basin. Thus, the resulting maps show the numerous residual basins that discharge their waters to the STP.

With regard to environmental tanks, the information provided by the different bodies in charge of infrastructures made it possible to draw up a map of the location of these rainwater storage systems. Hereby, the cartography results show the location of these tanks and the state in which they can be found. Thus, they have been classified into 3–4 categories: executed, in progress, planned and with a draft project, in the study area for both regions. Lastly, thanks to the data provided by these entities, it is possible to know the total storage capacity in the event that it reaches its maximum capacity and the volume of additional water that is incorporated into the volumes of water trafficked.

3. Results

3.1. Wastewater Use Basins: A Proposal for Adaptation to Climate Change

Climate projections related to rainfall show a decrease in annual totals, in the number of rainy days, as well as changes in the way it rains [3]. However, it has been shown that for every 1 °C of global warming, the moisture retention capacity increases by 7% [1,2] which causes more intense and voluminous rainfall [44,45], bearing in mind an increasingly warm Mediterranean Sea [2,46–51].

Climate models indicate that a warmer climate incites greater convective power and the genesis of storm cloud formations, which end up generating storm nuclei, convective trains or mesoscale systems, favoring the production of intense or torrential rainfall, with very high intensity and, affecting specific areas; that is, it rains in a very localized and concentrated way [2]. These types of formations are characterized by not traveling long distances, so the models agree that rainfall trends are concentrated in the first few kilometers of coastal areas or in the lower reaches of river basins [2].

These issues modify the hydrological cycle and hydrological planning, since they are unusable rains, as they do not precipitate in the headwaters of the main river basins, assuming a positive contribution to the headwaters regulated by reservoirs [52]. There are national studies that corroborate these statements [12,13,45,46].

In the Segura Hydrographic Demarcation, the episodes of intense and torrential rains are located in the first few kilometers of the coast, with negligible amounts reaching the headwaters of the Segura River and its main tributaries, which causes flooding in the lower course of the rivers and in coastal areas, and creates an opportunity to use rainwater that is currently beginning to have a notable boom. These episodes of torrential rains (e.g., years 2012, 2016, 2017 and 2019) clearly show the distribution or greater concentration in the first few kilometers of the coastal areas of the Segura basin (Figure 6).

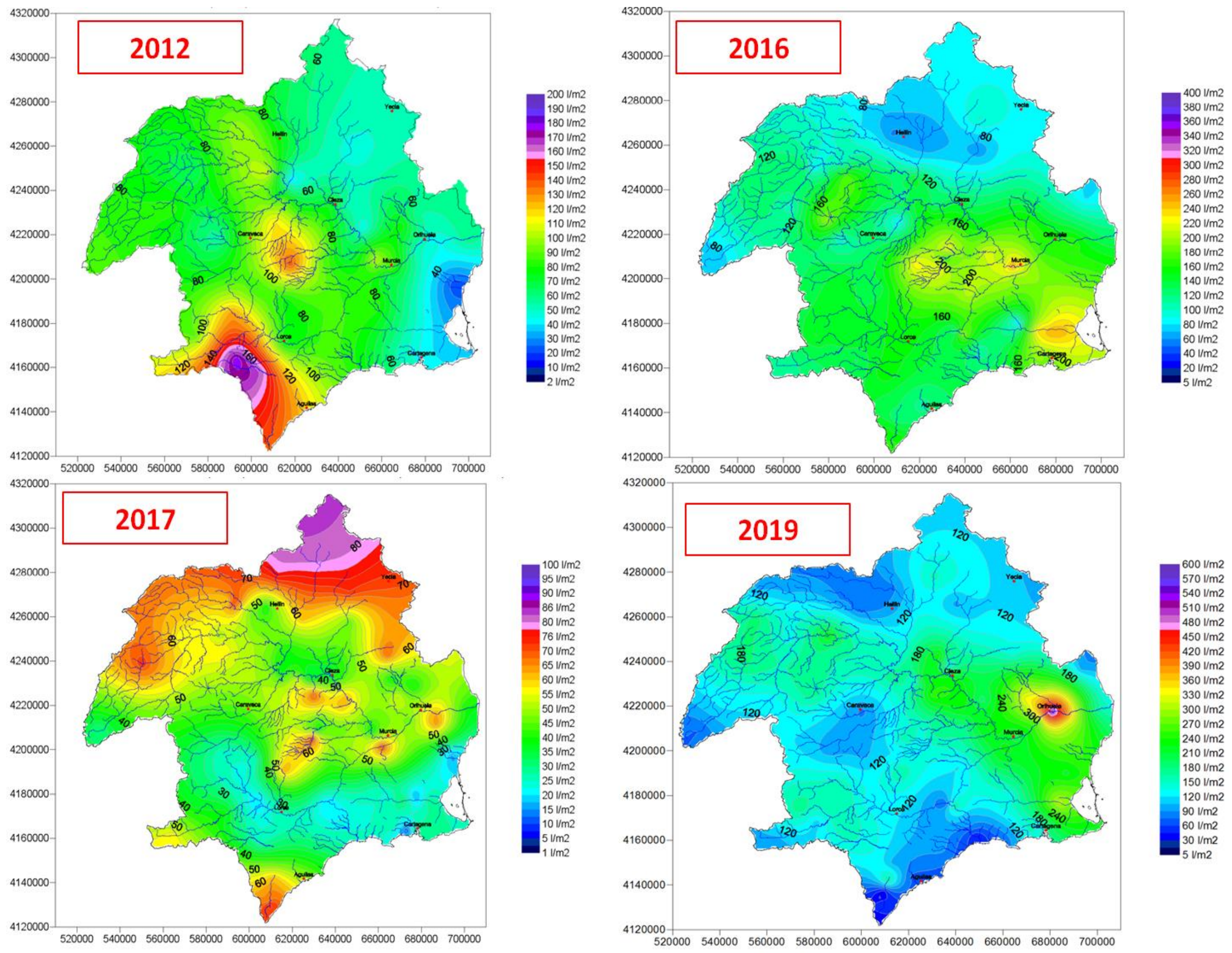

Figure 6. Episodes of torrential rains in the Segura Hydrographic Demarcation (2012, 2016, 2017 and 2019). Source: Segura Hydrographic Demarcation (DHS). Liters per square meter (l/m^2) are equivalent to millimeters (mm) of precipitation.

The torrential rainfall episodes of the years 2012, 2016, 2017 and 2019 are located in the middle and lower sections of the main river courses, which caused flooding in these territories. However, in relation to the objectives of this research, this type of rain is presented as an opportunity to use rainwater along with sewage which, under the concept of the wastewater use basin, allows the collection of rainwater which is treated in the nearest STPs so that, later, the treated water is for use and reuse in agriculture and urban uses (irrigation of parks and gardens, street cleaning, fires . . .). This is why this proposed concept of the "wastewater use basin" acquires importance and applicability, as a commitment to adaptation to climate extremes and climate change in semi-arid and arid regions, and applicable to other regions with more humid climates. This concept integrates the flows of sewage and stormwater, and the management of floods, since depending on the runoff in that catchment basin, the capacity of the STP will be planned, the types of treatment, and where to locate the deposits (including environmental tanks) in anticipation of torrential precipitation events.

The resulting maps show the delimitation of the "wastewater use basins" of the study areas. For greater detail of the results, these are shown in two study subzones corresponding to the Campo of Cartagena-Mar Menor district (Murcia Region, Spain) (Figure 7) and the Vega Baja district (Alicante, Valencian Community, Spain) (Figure 8).

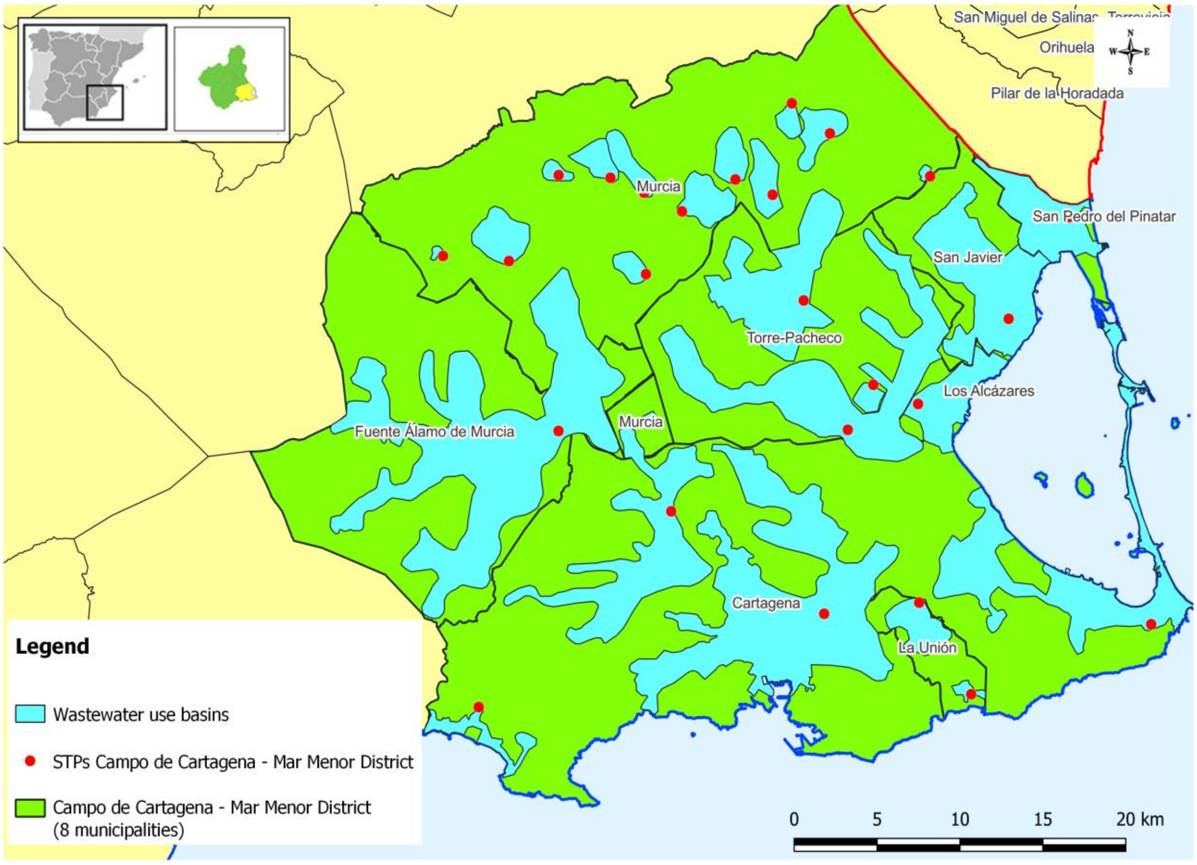

Figure 7. STPs and their wastewater use basins in the Campo of Cartagena–Mar Menor district. Source: Bernabé-Crespo, Olcina and Lahora [15].

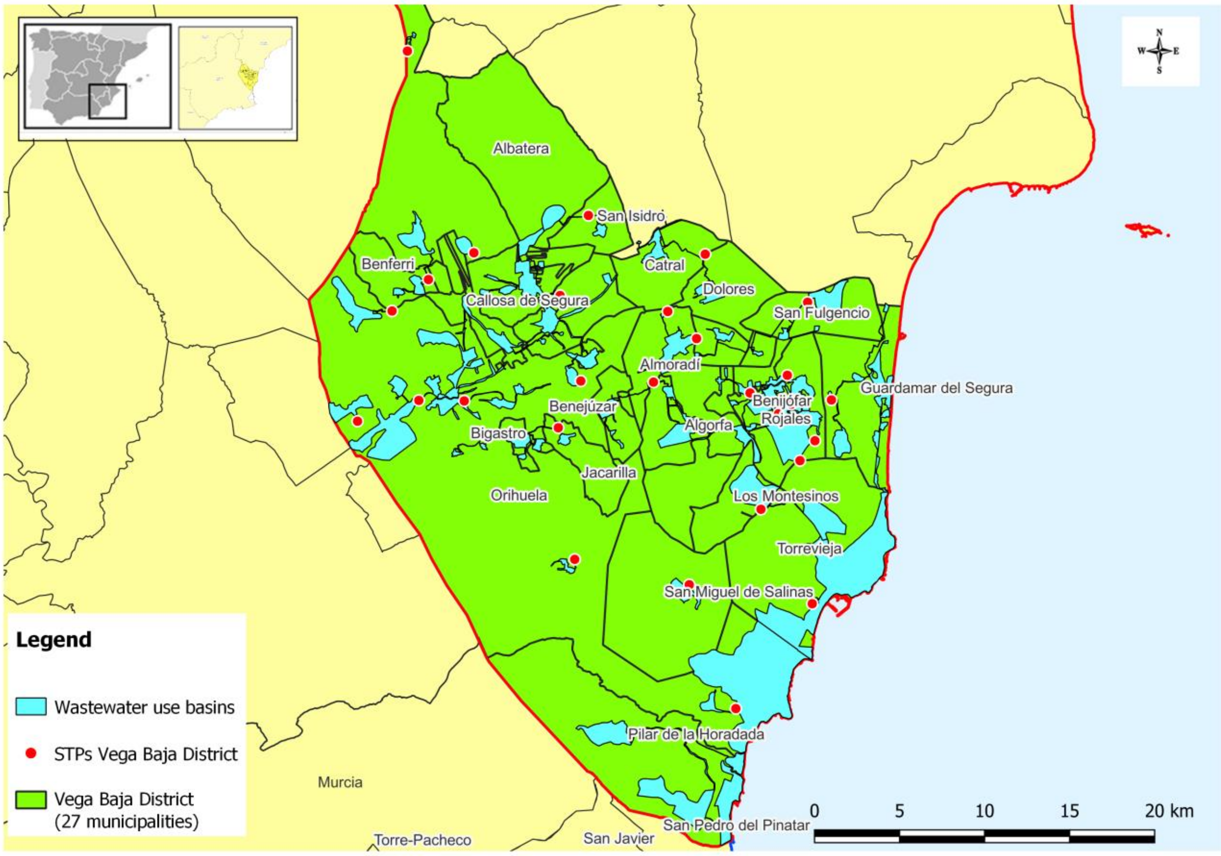

Figure 8. STPs and their wastewater use basins in Vega Baja district (Alicante). Source: EPSAR and ICV. Own elaboration.

Figures 7 and 8 show the location of each of the STPs found in both districts. In Campo of Cartagena–Mar Menor, a total of 25 STPs supply more than 360,000 inhabitants, and in the Vega Baja district, a total of 32 STPs supply a population of 350,000 inhabitants. In both spaces, in the summer months the population triples, so the demand for water increases exponentially. This means that the existing wastewater treatment plants treat the water consumed by the permanent residents of both districts. In the summer months, due to massive sun and beach tourism, coupled with residential tourism (single-family homes, natural lawns and swimming pool infills, among others) and recreational areas that use water, water consumption is higher. Therefore, the wastewater treatment plants receive a greater volume of wastewater during the summer months.

The increase in water consumption by the population in the summer months implies an increase in the volume of water treated by the treatment plants. However, this is not considered a positive aspect as it means higher water consumption. Once treated, the water is reused in agriculture or for urban and industrial uses, but it is not used for urban supply or water consumption.

Therefore, the only way to increase the volume of water in wastewater treatment plants without increasing water consumption is to incorporate rainwater. Hence, the proposal for integrated water management of urban environments through the concept of "wastewater use basis", including wastewater and stormwater.

The Vega Baja treatment plants, as a whole, purify around 24–25 hm^3 in a year, even though they are designed with a maximum capacity of 58–60 hm^3 per year. In the Campo of Cartagena–Mar Menor district, the treated flow exceeds 18 hm^3 per year and, as a whole, the design capacity exceeds 70 hm^3 per year [53]. This implies that all these STPs have a capacity of more than double to increase their volume of treated water with resources from other origins, such as rainwater.

As it is a resource from an alternative or adaptive source, it is not subjected to climatic variations, since it depends on the human consumption of the population. Potable consumption holds the priority place in water legislation for the purposes of meeting water demands.

Another key aspect to take into account is that, of the total volume of water treated in the Vega Baja district, more than half of these waters only comply with the parameters and conditions for discharge. This is due to the fact that most of the STPs in Vega Baja have secondary treatment (24 STPs) compared to those that have tertiary treatment (8 STPs). However, the EPSAR recently presented a works plan to expand the tertiary treatment and improve the processes of a total of 20 STPs in the district, and the construction of a new treatment plant in Almoradí. In the case of Campo of Cartagena–Mar Menor district, all STPs comply with Directive 91/271, which dictates the parameters for the discharge of urban sewage. In addition, out of the 25 STPs, only 6 do not have tertiary treatment. These correspond to those with the lowest treatment capacity and they are linked to urban developments with a golf course, so their priority use is to irrigate the lawns. Only the Mar Menor Sur STP does not have tertiary treatment, as it is carried out in the adjacent desalination plant used by the Arco Sur Mar Menor Irrigation Community.

In Vega Baja, the problem lies in the fact that these treated waters with secondary treatment are discharged into the channel or pertinent irrigation networks (irrigation canals) that are used indirectly for irrigation. These waters are not of sufficient quality to be reused to irrigate crops, although many irrigators use them, since farmers irrigate through these canals. Those waters treated with tertiary treatment, in general, are not discharged into any channel or irrigation canal, but they are reused. The Segura Hydrographic Confederation makes concessions of this water to different users, such as Irrigation Communities, or it is reused for street washing, park and garden watering, and firefighting, among other urban uses.

In this line, and taking into account the rainfall trend in the Segura hydrographic basin, the concept of the wastewater use basin is presented as an opportunity to source additional resources that increase the volume of water treated by the STP, and which can be used for different uses. Another opportunity resulting from the sewage management and the implementation of the wastewater use basin concept is the possibility of undertaking potable reuse projects for human consumption [30].

3.2. Planning and Management of Rainwater for Its Incorporation into a STP in the Southeast of the Iberian Peninsula

Both in the Campo of Cartagena–Mar Menor and the Vega Baja districts, the sanitation network is unitary (sewage and rainwater in the same collector), although in some areas they have a mixed sanitation network (sewage in one collector and rainwater in another collector), and gather rainwater from urban areas, in addition to the wastewater flows generated. With the objective of reducing the danger of urban floods, many cities have begun to design sustainable systems for the circulation of rainwater, through the construction of large-capacity collectors, environmental tanks or stormwaters [42] and flood parks, at the same time incorporating green infrastructure [54].

Regarding the Campo of Cartagena–Mar Menor district, there is a network of environmental tanks which means that an important part of the rainwater that falls in each wastewater use basin is treated in the STP and later reused (Figure 9).

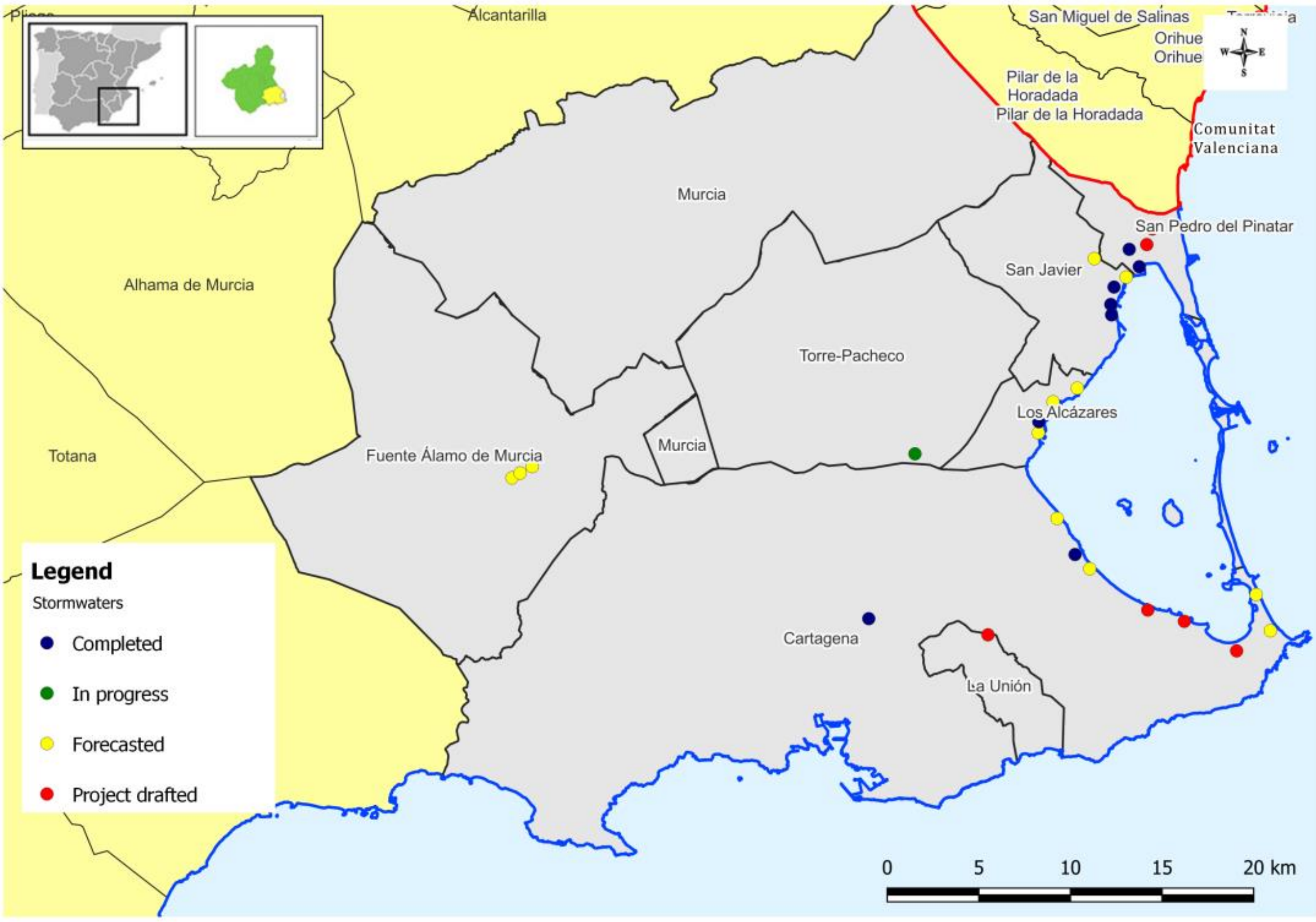

Figure 9. Location of the network of environmental tanks built and projected in the Campo of Cartagena–Mar Menor district. Source: General Directorate of Water, Regional Office of Water, Agriculture, Livestock, Fisheries and the Environment of the Autonomous Community of the Region of Murcia (CARM, 2023). Own Elaboration.

At present, the autonomous administration of the Region of Murcia has built a total of 9 environmental tanks in the study area that add up to a maximum rainwater retention capacity of 101,372 m^3 distributed in 5 municipalities (Table 1), compared to the 14 total in the whole district.

Table 1. Maximum rainwater retention capacity in existing environmental tanks in the Campo of Cartagena–Mar Menor district.

Municipality	Maximum Retention Capacity of the Set of Existing Environmental Tanks (m^3)
Cartagena	19,250
Los Alcázares	3865
San Javier	12,032
San Pedro del Pinatar	6225
Torre Pacheco	66,000
TOTAL	107,372

Notes: Source: General Directorate of Water, Regional Office of Water, Agriculture, Livestock, Fisheries and the Environment of the Autonomous Community of the Region of Murcia (CARM, 2023). Own Elaboration.

Likewise, a total of 14 environmental tanks are planned to be built, totaling more than 100,000 m^3 per year, approximately (Table 2). There are draft projects for 3 environmental tanks by CARM (2 of them in Cartagena, of 2000 and 3500 m^3, and another 1 in San Pedro del Pinatar, of 10,000 m^3. In addition to those listed by CARM, there are others planned in the protection document for the Mar Menor lagoon: 2 in San Javier, 1 in San Pedro del Pinatar, 3 in Los Alcázares, and 4 in Cartagena. A floodplain in San Javier is also close to tender. For its part, ESAMUR is building another environmental tank near La Unión STP.

Table 2. Maximum rainwater retention capacity in the environmental tanks projected in the Campo of Cartagena–Mar Menor district.

Municipality	Maximum Retention Capacity of the Set of Projected Environmental Tanks (m^3)
Cartagena	5500
San Pedro del Pinatar	10,000
La Unión	3300
San Javier	No data
Los Alcázares	No data
TOTAL	

Notes: Source: General Directorate of Water, Regional Office of Water, Agriculture, Livestock, Fisheries and the Environment of the Autonomous Community of the Region of Murcia (CARM, 2023). Own Elaboration.

Between the existing ones and those projected in the Campo of Cartagena–Mar Menor district, they add up to a total of almost 20,000 m^3, which could be incorporated into the volume of water treated in the STPs in each wastewater use basin.

In the case of the Vega Baja district, unlike in Campo of Cartagena–Mar Menor, there is no extensive network of environmental tanks. There are only 4 rainwater storage devices or environmental tanks (Table 3). As shown, the number of environmental tanks and their total capacity are very low, barely 10,500 m^3.

Table 3. Maximum rainwater retention capacity in existing environmental tanks in the Vega Baja district.

Municipality	Maximum Retention Capacity of the Set of Existing Environmental Tanks (m^3)
Rojales	5000
Daya Nueva	500
San Fulgencio	0 *
San Isidro	5000
TOTAL	10,500

Notes: * Listed in the Vega Renhace Plan. This is a floodplain that accumulates water but evacuates it soon after. Source: own elaboration.

It should be highlighted that, with the implementation of the Vega Renhace Plan, the construction of more than 90 environmental tanks in the Vega Baja district (Figure 10) has been proposed by the municipalities, being financed by the autonomous administration. Of them, the environmental tank of San Isidro is already built.

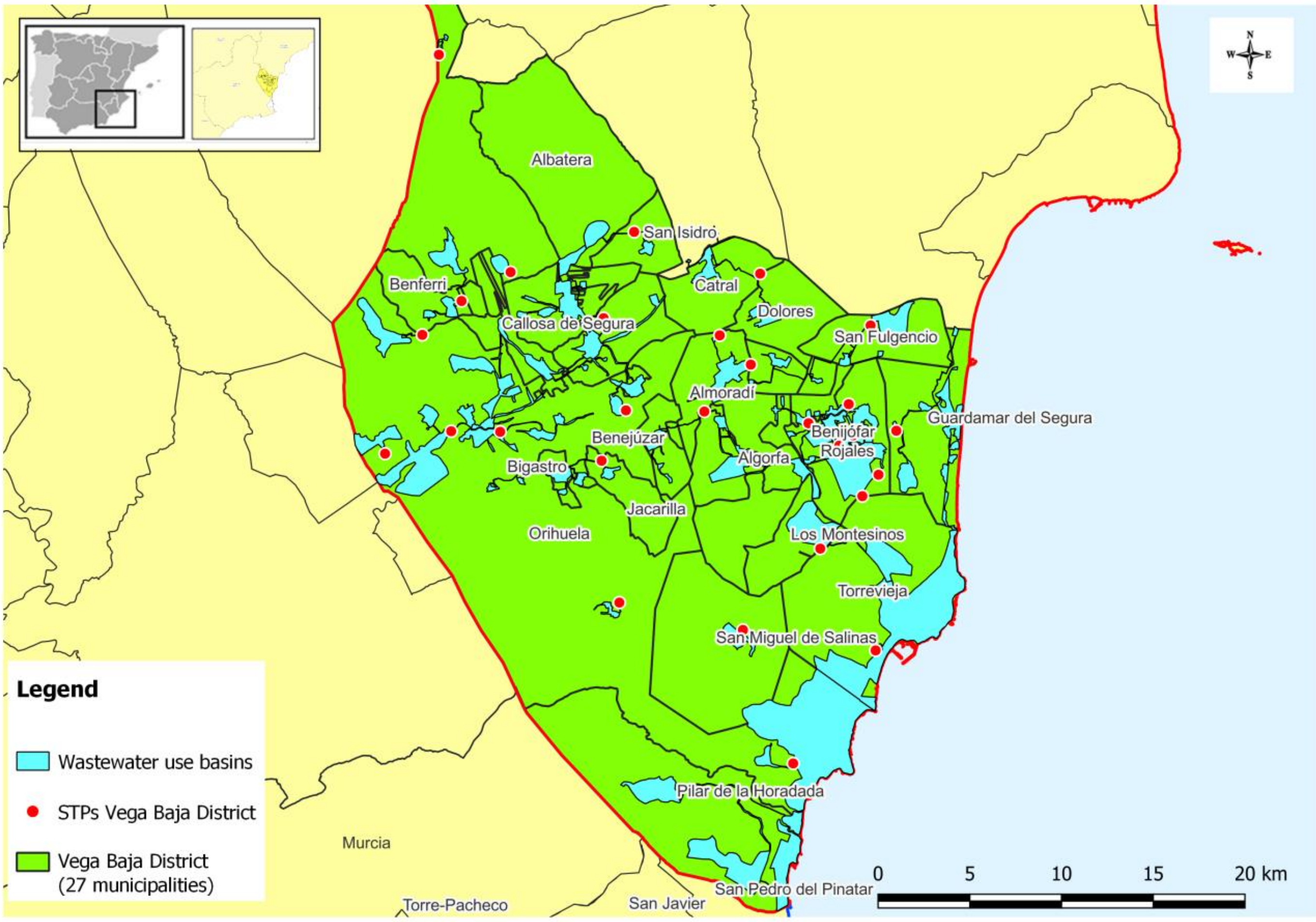

Figure 10. Location of the network of environmental tanks built and projected in the Vega Baja district. Source: Plan Vega Renhace. Own elaboration.

According to the information featured by the Regional Plan for Sustainable Urban Drainage Systems within the framework of the Vega Renhace Plan, there is an average of construction proposals of 2 environmental tanks in each municipality. Adding the existing environmental tanks and the more than 90 projected environmental tanks, they add up to a total maximum rainwater retention capacity of 2,749,390 m^3 (Table 4).

Considering this, it can be ensured that the maximum rainwater harvesting capacity amounts to more than 3,000,000 m^3, that is, between 3–3.5 hm^3, which is a noteworthy additional volume of water, important and complementary to existing water resources. Especially, it is presented as a way to capture and increase the volume of flows treated by the STPs. Combining the maximum capacity between the existing and projected environmental tanks in the study area, for both regions, a maximum volume of 4 hm^3 could be reached, which would increase the volume of water treated in the existing STPs, with an additional volume of rainwater.

Table 4. Maximum rainwater retention capacity in the environmental tanks projected in the Vega Baja district.

Municipality	Maximum Retention Capacity of the Set of Projected Environmental Tanks (m^3)
Albatera	30,000
Algorfa	84,455
Almoradí	281,994
Benejúzar	55,645
Benferri	6000
Benijófar	37,505
Bigastro	97,581
Callosa de Segura	20,000
Catral	68,635
Cox	153,601
Daya Nueva	6397
Daya Vieja	7415
Dolores	65
Formentera del Segura	7910
Guardamar del Segura	22,300
Granja de Rocamora	800,000
Jacarilla	13,660
Los Montesinos	57,537
Orihuela *	376,028
Pilar de la Horadada	170,400
Rafal	20,573
Redován	72,785
Rojales	202,137
San Fulgencio	15,007
San Isidro	5000
San Miguel de Salinas	135,760
Torrevieja	ND **
TOTAL	2,749,390

Notes: * There are projected environmental tanks, but their maximum capacity is unknown since they are not reflected in the Regional Master Plan. ** ND: No data. Source: Own elaboration.

4. Discussion

Climate change forecasts and competition for the uses of water in regions with water scarcity make it urgent and a priority to deepen the management of rainwater and sewage.

The results evidenced the applicability of the concept of the wastewater use basin for the use of rainwater and sewage that feed a STP to be treated in a proper way and be directly and indirectly reused. The rainwater included in the wastewater use basin of an STP means an increase in the volume of additional water that the treatment plants can offer.

From this perspective, in order to complement an adequate and rational planning and management of rainwater, the creation of a mixed sanitation network (sewage and rainwater) in urban centers must be supported. The rainwater collectors must flow into storage devices or environmental tanks that have two objectives: (a) prevent the first water from being discharged directly into natural aquatic systems, since they are the most polluted since they perform the cleaning function, washing asphalt and dragging solid urban waste, and (b) storing rainwater to relieve the collectors and, later, being reused for agricultural, industrial, urban, leisure sports and tourist uses, among others [28].

For these reasons, it is necessary to promote the implementation of the concept of the "wastewater use basin" and to incorporate it into hydrological planning in the context of the transposition of the new European regulation 741/2020 that comes into force in 2023.

European Regulation 2020/741 of the European Parliament and of the Council, of 25 May 2020, on the minimum requirements for water reuse, will enter into force on 26 June 2023. This regulation adopts an approach based on the elaboration of a Risk Management Plan by all responsible parties. In order to produce, supply and use reclaimed water, the relevant national authority should ensure that a reclaimed-water risk management plan is developed. In particular, all additional water quality requirements must be established, and determine appropriate preventive measures and/or possible corrective measures, as well as barriers or additional measures to ensure the safety of the system.

The administrative procedures required to comply with the Regulation are currently under development in accordance with local conditions (including the basin organization as the competent authority). It is also time to develop new legislation to promote the reuse of water for agriculture and other uses (it could also be argued, for potable reuse). It is necessary to adapt the current Royal Decree 1620/2007 to the new legal framework and establish a cost sharing system in the management of reclaimed water.

As mentioned above, potable reuse might be considered. In the light of this, potable reuse is a fact in many areas of the world, such as Singapore, California, Namibia and Australia, so exploring the implementation of this type of project is an adaptation strategy to be given consideration [30].

According to current legislation, drinking water is subject to Council Directive 98/83/CE of 3 November 1998 and its subsequent updates, on the quality of water intended for human consumption. In Spain, it is regulated by Royal Decree 902/2018, of July 20, which modifies Royal Decree 140/2003, of February 7, which establishes the sanitary criteria for the quality of water for human consumption. In Spain, potable reuse for human consumption is prohibited by Royal Decree 1620/2007, except in situations of disaster declaration. For its part, sewage must meet the quality criteria set out in the same Royal Decree 1620/2007 and in European Regulation 2020/741 for its application in irrigation. Since 1995, the different national sectoral plans for sanitation, purification and water quality have tried to achieve compliance with the regulations, ensuring water quality and zero discharge in coastal areas, promoting the reuse of reclaimed water for agricultural, environmental, recreational, industrial and urban use, and informing, sensitizing and raising awareness about the benefits of reusing water [55].

Despite the express prohibition of potable reuse in Spain, it should be noted that such a restriction depends on the legislation and social sensitivity and its representation and political will, manifesting as the greatest reluctance the so-called “yuck factor”, the instinctive rejection of what is unknown, fearful or unpleasant [56]. This situation can be overcome by society and accepted, after pilot experiences, awareness campaigns and political will, as shown by perception studies [57–62].

Although currently the major use of recycled water is its application in agriculture, Leverenz, Tchobanoglous and Asano [63] argue that this situation will change due to the process of increasing urban concentration, especially in coastal areas. In addition, it is also worth considering “de facto” indirect reuse, which entails discharges of reclaimed water into a river bed, which are captured as a supply resource downstream. For all these reasons, it is necessary to undertake greater protection of wastewater use basins, increasing surveillance, monitoring and regulation of discharges into the sewer. In this sense, ESAMUR carries out a real-time control of chemical contaminants to identify an uncontrolled discharge quickly and efficiently. In short, it is about ensuring that the flow that reaches a STP is safe, and that the sites whose discharges are of a more polluting nature, such as industrial complexes, have their own STP.

However, a series of aspects should be taken into consideration for the study area. Some authors have highlighted that the Vega Baja district is an example of 100% reuse of treated water [55,64], which implies a reuse of water per year that fluctuates between 24 and 26 hm^3/year. These volumes of water are usually used directly and indirectly. The latter is related to the discharges or effluents from the STPs in to the irrigation fields closest to the irrigation canals (acequias or azarbes), or through an underground conduit that discharges into the sea, in the case of those STPs closest to the coast. These data do not reflect the reality of water quality. As previously indicated, most of the Vega Baja STPs lack tertiary treatment in their facilities, which means that between 13 and 15 hm^3/year are discharged into irrigation canals, fulfilling the function of returned clean water to the Hydraulic Public Domain, and therefore, complying with environmental regulations. However, the water discharged into irrigation canals is used indirectly to irrigate crops, which poses a serious sanitary risk to human health, since it is water that is not prepared for irrigating crops. More notably, certain crops need to comply with a series of particular conditions. Therefore, the quality of the water is not so good, which is hidden under the statement that it is an example area of 100% reuse of water. Out of the total volume treated annually, only between 10–12 hm^3/year has received tertiary and/or additional treatment, which represents a percentage of 47–48% that can be reused for irrigation, complying with current wastewater regulations, and which are generally sent to the closest applicant Irrigation Communities, and stored in irrigation ponds, for later reuse.

Promoting this task, which implies managing and ordering the territory, also concerns the prevention of flooding risks: ensuring the correct functioning of the STPs implies laminating the floods of water and establishing infrastructures to prevent their collapse, which creates a territory adapted to torrential events. This is of vital importance in the Mediterranean region, one of its characteristics being the torrential rainfall at its equinoxes, increased by climate change. To this end, Spain occupies the fifth place in Europe by volume of population exposed to floods, with the Mediterranean coastal areas being the most vulnerable, those with the greatest risk from natural hazards [65,66].

The main aim of this work is to shed light on the concept of the wastewater use basin, its applicability, and its ability to obtain additional water resources of pluvial origin. In accordance, Olcina et al. [29] show that, in the case of the Alicante environmental tank (named José Manuel Obrero) built in 2011, it captured from 2013 to 2018 more than 2,000,000 m^3 and, in a later work, Hernández, Saurí and Morote [38] point out that between 2011 and 2019 that figure rose to 3,300,000 m^3, which has been reused for agricultural irrigation or urban green areas after treatment in a STP. These data are significant since they reinforce the idea of the use of wastewater use basins proposed in this research. Finally, it is convenient to highlight the lights and shadows that the wastewater-use basins have in arid and semi-arid regions (Table 5).

For all these reasons, it is considered an applicable concept that can be extrapolated to semi-arid and arid climatic regions of any part of the globe, as a proposal for adaptation to structural climatic extremes and to climate change. Likewise, it is a proposal and practice applicable to those regions of the world with more humid climates that have a greater capacity to use rainwater, applicable when situations of temporary drought are experienced in these spaces, whose effects on water resources are notable, with water supply cuts occurring for several hours a day.

Therefore, it represents adaptation measures in the current climate context and with a prospective vision of future climate scenarios. Moreover, it is a proposal that complies with the Sustainable Development Goals (SDG), the recommendations of the IPCC [2] and the reports published by the European Commission [67,68] that indicate that if adaptation and mitigation measures are not carried out today, in a decade they will be more expensive along with the impacts and consequences of climate change.

Table 5. Weaknesses and opportunities in the application of the concept of the wastewater use basin and use of environmental tanks in semi-arid and arid climates.

Weaknesses	Opportunities
Natural scarcity of conventional water resources	Use of non-conventional water resources to guarantee existing demands
Unfavorable climate projections for the regular assurance of water resources from precipitation	Technique for adaptation to climate change and atmospheric extremes
Need for treatment to improve the quality of urban effluent	"Stable" flows from urban/industrial water use
Rainwater stored in the storm tanks contains a high level of contamination from the dragging of solids on urban surfaces.	Incorporation of rainwater stored in environmental tanks to the set of unconventional resources to be reused.
Growing demands for agricultural and urban-tourist uses in areas with high socioeconomic dynamism.	With proper treatment and compliance with the sanitary parameters of European and state regulations, they can be reused for agricultural, industrial, urban, leisure-tourist and even drinking uses.
Threat of STP collapse in situations of heavy rains	Installation of environmental tanks that help to laminate the inlet flow to the STP and to prevent overflows and contamination of the environment
Scarce development (legislative and social) of potable reuse	Identification of the most suitable residual basins to develop pilot programs for potable reuse

Note: Source: own elaboration.

All these considerations are incorporated within the line of the so-called sustainable hydrological planning proposed by some authors, in order to establish a planning adapted to climatic extremes and the effects of climate change, according to possible warming scenarios [5]. For these reasons, researchers are encouraged to develop future research related to the concept of the wastewater use basin and sustainable hydrological planning.

5. Conclusions

The concept of the "wastewater use basin" is presented as a working unit of a smaller scale than traditional river basins, which allows for better management of the water collected in the sewerage network and rainwater. Both wastewater and rainwater collected by the urban collectors have the ultimate aim of diverting the water to the nearest wastewater treatment plant for specific treatment and, subsequently, reuse.

It is a proposal based on a geographical approach whose applicability allows a new planning of renewable water resources, from a smaller scale of work, betting on the self-supply of the territories of semi-arid and arid regions, the results of which are: (a) rainwater harvesting, (b) the increase of an additional volume of water to wastewater treatment plants that will increase their water supply, (c) allowing for the self-supply of urban agglomerations, (d) once reclaimed, the water can be used for agriculture, industrial uses, leisure or recreational uses and urban uses (irrigation of parks and gardens, street washing, ornamental fountains . . .), and even, (e) water use for human consumption.

This concept allows for greater planning for the collection and treatment of wastewater and stormwater, while reducing the risk of flooding. In addition, it allows for the storage and avoidance of urban pollutants carried by water, thus fulfilling an environmental function. It allows the maximum water storage capacity in rainy situations to be known, since it is a modern way of capturing and using water from intense and/or torrential rainfall, especially in areas of water scarcity. Finally, it allows greater adaptation to increased extreme weather events (droughts and floods) and is an adaptation measure to climate change in arid and semi-arid regions.

As future ideas for the extension of related studies in this line, research can be carried out based on: (1) the analysis of the level and quality of purification and regeneration of treated water in wastewater treatment plants, (2) whether treated water is reused directly or indirectly and, in the case of agriculture, which irrigation communities and cultivated areas benefit, (3) research related to increasing water volume in purification within river-basin hydrological planning, (4) a water management model based on self-supply and use of indigenous water resources, promoting a circular economy in semi-arid and arid regions, (5) adaptation measures to climate extremes (droughts and floods) and to the effects of climate change. These ideas are only a series of suggestions that can be expanded upon by other authors and future research.

Ultimately, this is a conceptual proposal whose application framework is important for the future of water planning in urban environments

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