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Geospatial analysis of desalination in the US – An interactive tool for socio-economic evaluations and decision support

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ABSTRACT

In the United States, desalination has considerably expanded since the 1950s, reaching a daily production capacity of 2 BGD (billion gallons per day) with around 1336 operating plants as of 2013 (GWI, 2013). Despite this continuous growth, a steady increase in desalination investments and growing demand for water, research on geospatial representation of desalination plants and their characteristics over time does not exist or is very limited. This paper aims at filling this gap by developing interactive 5D and 6D geospatial models and a multi-dimensional analysis of desalination trends in the time span 1950–2013. The analysis shows that desalination plants are located mainly on the East and West Coast of the United States, with Florida, California, and Texas leading in the national desalination sector. Despite the geographical proximity to the sea, most of the plants use brackish groundwater due to economic factors related to the desalination process itself and the disposal of the highly saline byproduct – brine. The models can be used both for educational and interdisciplinary research purposes and help with determining socio-economic viability of establishing prospective desalination plants in different regions in the future. They can also help support decision makers in solving emergency questions related to water shortages and preparing for long-term water scarcity in different US regions.

1. Introduction – Need and challenges for geographical representation of desalination plants in the US

As reported by the US Census Bureau (2012), the United States population is expected to increase by 31% by 2050. For many decades, water demand for food, fuel, industrial, and municipal consumption has been growing rapidly, while water resources have been shrinking either due to the aquifers depletion or due to unexpected weather events like drought. Thus, the availability of fresh water is endangered and poses a serious challenge for policy makers. Desalination is one of the technologies that could help mitigate this problem in the mid- and long-term.

With the total desalination capacity in the US of 2 BGD (billion gallons per day) and the total of 1336 operating plants in 2013, the US is competing with Saudi Arabia for the top place on the global desalination market in terms of the annual production capacity. The desalination sector has been growing exponentially since 1990s – the total capacity increased by 53 times and the total number of plants by 61 times between 1990 and 2013 (GWI, 2013). The annual rate of growth by the number of new desalination plants online (operating plants) in the US indicates long-term trends in the desalination sector (Fig. 1). At the same time, the total global investments in desalination reached the low of $3.5 billion in 2013 and are expected to grow up to $12 billion by 2018 (Gasson, 2013). Desalination is still an expensive technology, but it has a tremendous potential for '*enormous supply expansion that exceeds all likely demands*' (Chowdhury, Lant, & Dziegielewski, 2013).

Even though desalination has been successfully applied in the US as a reliable water supply source since 1950s, congruent and detailed information on the respective desalination plants is still missing to date. The collection of desalination data is extremely difficult mainly because of constant dynamics in the desalination sector, while it is also stymied by private BOT (Build-Operate-Transfer) arrangements between municipal water authorities and construction companies that do not always allow for the information to become a public record for many years after the desalination plants are built.

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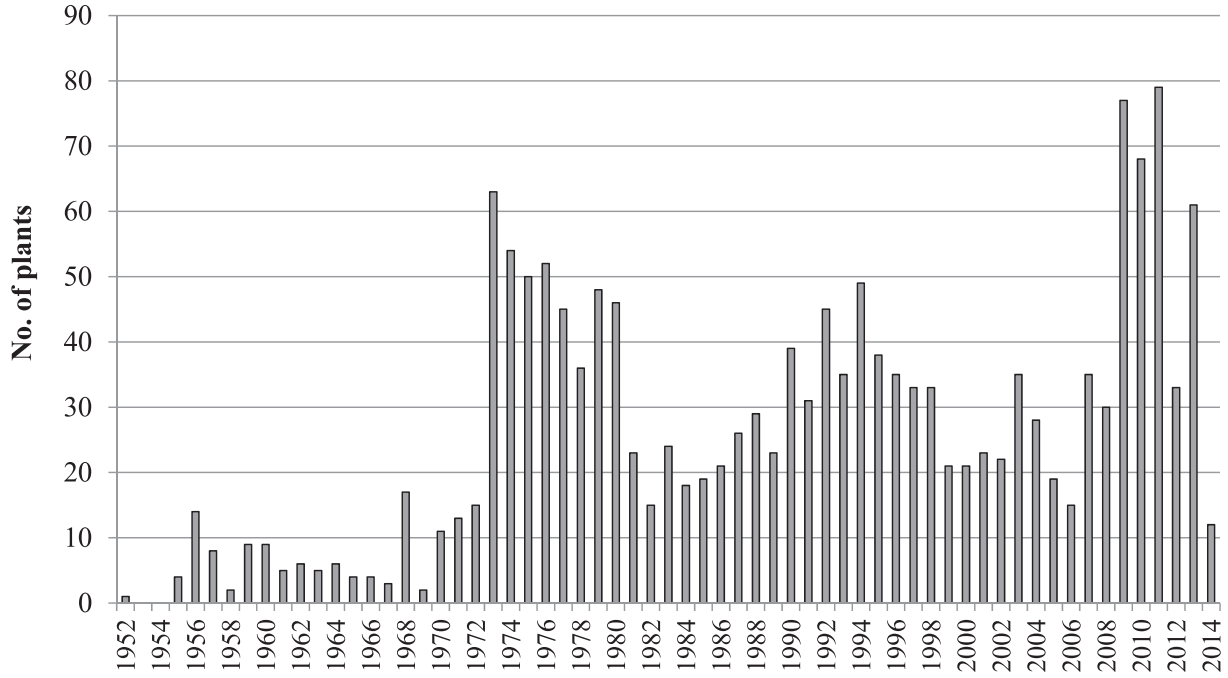

Fig. 1. New desalination plants online in the US per annum.
Source: Authors' presentation based on GWI (2013)

Due to data paucity, most researchers attempt to compile desalination information based on regional case studies (Cooley, Gleick, & Wolff, 2006, Cooley and Ajami, 2012; WUIM, 2009). Those studies represent only a limited selection of existing desalination plants or future anticipated projects without any detailed specifications; and thus they do not provide enough input to depict a comprehensive picture of the desalination sector in the US. In addition, the regional data is often outdated and not comparable among regions, due to diverse methodologies applied for different case studies in different regions.

Several studies have attempted to combine and map desalination projects, however, with a limited success. For instance, Cooley et al. (2006) depicted trends on the global desalination market and mapped only the recently proposed desalination plants in California as of spring 2006. In 2014, the Bureau of Reclamation (2014) represented solely the single numbers of the most recent desalination projects[1] in the respective states, without providing detailed and specific information about those projects or their geolocation. Similarly, TWDB (2014) displayed only the largest plants in Texas, also missing on providing detailed information and a broader regional analysis. At the international level, similar attempts have been undertaken by Höpner and Lattemann (2002), Lattemann and Höpner (2008), and Dawoud and Al Mulla (2012) to map regional seawater desalination capacity in the Arabian Gulf. However, those studies have not been more comprehensive in terms of mapping desalination plants than the studies conducted in the US.

As of today, comprehensive studies are missing that would provide detailed geographic interactive maps of desalination plants in the US, and – due to the difficulties described above – no scientific effort has been taken to provide a compiled tool (model) to analyze all desalination plants in the country in a congruent way. This paper aims at filling this gap by developing five- and six-dimensional (5D and 6D) interactive models that represent desalination plants in the US in a geospatial location over the last six decades. This research coincides with a study by Eckert, Giger, and Messerli (2016) who emphasized that a detailed spatial analysis is necessary to draw meaningful conclusions about the phenomena under investigation. By including a set of uniform variables for all analyzed plants (feed water, establishment date, production capacity, users of desalinated water) in one interactive geospatial and temporal map, the models and visual representation allow for comparison analyses among plants and regions.

The models present the desalination sector on a macro scale. They can be used for analyzing trends in desalination as they address both changes in the plant status (online, offline, mothballed, decommissioned, under construction, etc.) and changes in desalination capacity at all those plants over time since 1950s. The models are 3D fly-through clickable GIS maps with a Radio folder feature selection function allowing for turning on and off different feature layers and categories, depending on the conduced analysis. This determined the interactive capability of the model and allows the user to explore different multi-dimensional GIS features of desalination plants presented with the model. This model functionality also fosters quick learning and provides the user with a tool for an in-depth multi-dimensional exploration of the trends and changes in the desalination sector.

The models are multi-dimensional which means that they combine multiple categories describing desalination plants: 1) location – represented with the lat long (and the x, y axes) describing the geospatial feature, 2) time – represented with the elevation (and the z axis) describing spatio-temporal feature, and 3) additional desalination characteristics, such as feed water, capacity, plant status, and the user category. Those categories allow for the exact geographical and temporal determination and specification of the desalination plants in the US, including all the above mentioned characteristics simultaneously. The information generated with the models can be useful for estimating socio-economic viability of new desalination plants in the specific geographical

[1] A desalination project should be understood as a pilot project used for assessing validity of establishing a desalination plant in a given location in the future.