Past and modern water problems: Progress or regression?

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Abstract
Human needs related to water storage, transfer and utilization triggered technological advancements since prehistoric times in all civilizations. A comparison of technological solutions to water problems in ancient and modern Greece reveals that, while the present day technologies are obviously superior, the underlying design principles are not different in the two cases, while it is questionable whether there has been any progress with respect to durability, sustainability and balance in water technology and management. Furthermore, it can be supported that the present day approaches manifest a regression in that logos, logic and rational inquiry tend to be abandoned and replaced by stereotypes and doctrines, particularly those related to the environmentalist ideology, which have obstructed progress during recent decades.

Keywords: water resources development, water resources management, ancient technologies, Greece, developing countries, soft path

Introduction

Human societies have always appreciated water and have tried to resolve problems related to its storage, transfer, utilization and management. Technological achievements to resolve such problems began in prehistory, in several civilizations in Mesopotamia, Egypt, India and Greece (Mays et al., 2007) and aimed to control the flow of water, initially for agricultural needs (irrigation) and later for urban needs (water supply and sewerage). Remains of prehistoric irrigation canals, as well as urban water systems still exist. It is a historical fact that technological applications to solve practical problems preceded the development of scientific knowledge.

Ancient water technologies are not necessarily dissimilar to modern ones. Sometimes ancient systems have been admired by modern day engineers, as the following quotation, related to water technologies in Minoan Crete, indicates:

> *We frequently hear people speak of "modern sanitation" as if it were something rather recently developed, and there appears to be a prevalent idea that municipal sewerage is a very modern thing that began some time about the middle of the last* [19th] *century. Perhaps these ideas do something to bolster up a somewhat wobbly pride in modern civilization* […]*, but when examined in the light of history these ideas are seen to be far from new or even recent. Indeed,* ***in the light of history it is a matter of astonishment, if not chagrin, that man in this respect has progressed so very little, if at all, in some four thousand years***. […] ***All in all, the***

> ***archaeological researchers on this*** **[Minoan]** ***site yield a picture of a people who had progressed far along the path of comfortable and hygienic living, with a considerable degree of beauty and luxury in the surroundings. And this had been accomplished some four thousand years ago.***
>
> *(H. F. Gray, 1940; emphasis added)*

In particular, the ancient civilizations that bloomed in different periods in Greece developed advanced knowledge, technologies and practices which greatly influenced our contemporary science and technology. As the prolific American writer, historian, and philosopher Will Durant (1939: vii- viii) put it:

> *Excepting machinery, there is hardly anything secular in our culture that does not come from Greece.*

Obviously, there are many conceivable reasons, as well as historical coincidences, which led to the advanced cultural and technological developments in Greece. Arguably, one of them is the limited natural sources which triggered invention and innovation in an attempt to find ways to satisfy human needs under scarcity. Earlier civilizations bloomed in large river valleys, which had water and soil resources in abundance (Mesopotamia near Tigris and Euphrates, Egypt near Nile, India near Indus). However, Greece does not have large rivers. Although in Western Greece there are some rivers with substantial flow, and in Central and Northern Greece there are some fertile plains, it is most interesting that the significant cultural centres (including Athens, Crete and Cyclades) grew not in these naturally richer places, but in poorer ones characterized by scarcity of water and soil resources. The Greek mythology offers a metaphorical and symbolic story about the relationship of scarcity with wisdom, i.e. the myth of the competition of Athena and Poseidon (Koutsoyiannis and Patrikiou, 2014). Athenians, in order to choose their patron god, organized a competition for the two prevalent candidates: Athena (goddess of wisdom, as well as of household arts and crafts) and Poseidon (god of waters). The one who would offer the best gift to the city, would be the winner. Poseidon offered abundant water by creating a well in Acropolis. Athena offered the olive tree, a tree with an amazing ability to live in poor soil under water scarcity, and an explanation why it would be wiser to choose her gift. Athenians opted for wisdom neglecting the opportunity for water abundance, which means that scarcity is not seen as a punishment but as a choice. This can be paralleled to the known biblical story of Adam and Eve: To obtain knowledge, they were led out of the abundance of Paradise to live in scarcity and fatigue. This is typically seen as a punishment as the loss of an easy-going paradise is difficult to conceive as a possible choice.

Arguably, the need is the mother of creativity and this should be the real reason that triggered progress in scarcity. As put by Plato:

> *ἴθι δή, ἦν δ' ἐγώ, τῷ λόγῳ ἐξ ἀρχῆς ποιῶμεν πόλιν: ποιήσει δὲ αὐτήν, ὡς ἔοικεν, ἡ ἡμετέρα χρεία.*

> *Come, then, let us create a city from the beginning, in our theory.* ***Its real creator****, as it appears, will be* ***our needs****.*
>
> (Plato, Republic, 2.369c; emphasis added)

Social friction driven by richness of resources, as opposed to fewer social strives for the procession of poorer areas, is another reason for the observed cultural progress, particularly in the case of Athens, as explained by Thucydides:

> *μάλιστα δὲ τῆς γῆς ἡ ἀρίστη αἰεὶ τὰς μεταβολὰς τῶν οἰκητόρων εἶχεν, ἥ τε νῦν Θεσσαλία καλουμένη καὶ Βοιωτία Πελοποννήσου τε τὰ πολλὰ πλὴν Ἀρκαδίας, τῆς τε ἄλλης ὅσα ἦν κράτιστα. διὰ γὰρ ἀρετὴν γῆς αἵ τε δυνάμεις τισὶ μείζους ἐγγιγνόμεναι στάσεις ἐνεποίουν ἐξ ὧν ἐφθείροντο, καὶ ἅμα ὑπὸ ἀλλοφύλων μᾶλλον ἐπεβουλεύοντο. τὴν γοῦν Ἀττικὴν ἐκ τοῦ ἐπὶ πλεῖστον διὰ τὸ λεπτόγεων ἀστασίαστον οὖσαν ἄνθρωποι ᾤκουν οἱ αὐτοὶ αἰεί. καὶ παράδειγμα τόδε τοῦ λόγου οὐκ ἐλάχιστόν ἐστι διὰ τὰς μετοικίας ἐς τὰ ἄλλα μὴ ὁμοίως αὐξηθῆναι: ἐκ γὰρ τῆς ἄλλης Ἑλλάδος οἱ πολέμῳ ἢ στάσει ἐκπίπτοντες παρ' Ἀθηναίους οἱ δυνατώτατοι ὡς βέβαιον ὂν ἀνεχώρουν, καὶ πολῖται γιγνόμενοι εὐθὺς ἀπὸ παλαιοῦ μείζω ἔτι ἐποίησαν πλήθει ἀνθρώπων τὴν πόλιν, ὥστε καὶ ἐς Ἰωνίαν ὕστερον ὡς οὐχ ἱκανῆς οὔσης τῆς Ἀττικῆς ἀποικίας ἐξέπεμψαν.*
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> ***The richest soils were always most subject to this change of masters****; such as the district now called Thessaly, Boeotia, most of the Peloponnese, Arcadia excepted, and the most fertile parts of the rest of Hellas.* ***The goodness of the land favoured the aggrandizement of particular individuals, and thus created faction which proved a fertile source of ruin****. It also invited invasion.* ***Accordingly Attica, from the poverty of its soil enjoying from a very remote period freedom from faction****, never changed its inhabitants. And here is no inconsiderable exemplification of my assertion that the migrations were the cause of there being no correspondent growth in other parts. The most powerful victims of war or faction from the rest of Hellas took refuge with the Athenians as a safe retreat; and at an early period, becoming naturalized, swelled the already large population of the city to such a height that Attica became at last too small to hold them, and they had to send out colonies to Ionia.*
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> (Thucydides, The Peloponnesian War, 1.2.3-6; emphasis added; English translation: Richard Crawley, www.gutenberg.org/files/7142/7142-h/7142-h.htm)

Friction, crisis and war were frequent in ancient Greece and determined the planning and design of cities and their infrastructures. The urban water systems were also designed according to the criterion of resilience in case of war, as concluded from the following passage from Aristotle:

> *ὑδάτων τε καὶ ναμάτων μάλιστα μὲν ὑπάρχειν πλῆθος οἰκεῖον, εἰ δὲ μή, τοῦτό γε εὕρηται διὰ τοῦ κατασκευάζειν ὑποδοχὰς ὀμβρίοις ὕδασιν ἀφθόνους καὶ μεγάλας, ὥστε μηδέποτε ὑπολείπειν εἰργομένους τῆς χώρας διὰ πόλεμον*

> *…and* [the city] *must possess if possible a plentiful natural supply of pools and springs, but failing this, a mode has been invented of supplying water by means of constructing an abundance of large reservoirs for rainwater, so that a supply may never fail the citizens when they are debarred from their territory by war"*
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> (Aristotle, Politics, 7, 1330b; translation from hydra.perseus.tufts.edu/)

Although it is difficult to infer the design principles of ancient engineers, we can hypothesize that their design criteria for water systems, in addition to security in war periods, also included durability, maintainability and sustainability (Koutsoyiannis et al. 2008). This is supported by the fact that several ancient hydraulic works have operated for very long periods, until contemporary times (see next section). Such criteria are not used anymore; current-day engineers typically use a design period of structures of about 40 to 50 years, which is related to economic considerations.

The urban water system in Ancient Athens

Athens can serve as an illustrative example to study ancient water systems and their management because of the many sources of information both from written texts and archaeological evidence. Athens is one of the driest places of Greece, currently receiving only 400 mm or rainfall per year, while there are no indications that the climate was very different in the antiquity. Under this hydroclimatic regime, the flow in the small rivers of the area is sustained only in the winter, while in the summer the ephemeral rivers are typically dried. Naturally, the lack of natural water availability triggered technology-enabled water resources and the scarcity prompted sophisticated technology-enabled systems comprising both large- and small-scale constructions, as well as a wise management system involving both the public and the private sector.

The entire urban water system of ancient Athens can be summarized in the following points (Koutsoyiannis et al., 2008; Zarkadoulas et al., 2012):

- A plethora of wells were dug from prehistoric times and were expanded through subsequent periods. During the archaeological excavation of the ancient Athenian agora by the American School of Classical Studies at Athens over 400 wells, both public and private, were found.
- The scarce natural springs (e.g. the famous Kallirhoe spring) were converted into elaborate fountain houses (e.g. Enneakrounos).
- Several aqueducts were constructed to convey water to the city from the nearby mountains. The first one was constructed in the sixth century BC and is known as the Peisistratean aqueduct (due to the tyrant Peisistratos who was in power then). The largest part of the aqueduct was carved as a tunnel at depths reaching 14 m, at the bottom of which a pipe made of ceramic sections was placed. Other aqueducts were also constructed with similar technologies in several phases forming a network of pipelines (Chiotis and Chioti 2012). The last and longest one (25 km), the Hadrianean aqueduct, was constructed in Roman times.
- Numerous cisterns receiving rainwater from roofs completed the structure of urban water system; mostly they date from the fourth to the first centuries BC. The

rationale behind these small-scale constructions is explained by the above mentioned quote by Aristotle, emphasizing the importance of water safety during war. In several cases, the cisterns were interconnected to each other and to wells, forming complex systems that stored groundwater and rainwater (Chiotis and Chioti 2012).

- Legislation has been an important element of the water management. The first known water control regulations of the Athenian city-state were made by Solon in the beginning of the sixth century BC. According to these regulations:

> *ἐπεὶ δὲ πρὸς ὕδωρ οὔτε ποταμοῖς ἐστιν ἀενάοις οὔτε λίμναις τισὶν οὔτ' ἀφθόνοις πηγαῖς ἡ χώρα διαρκής, ἀλλ' οἱ πλεῖστοι φρέασι ποιητοῖς ἐχρῶντο, νόμον ἔγραψεν, ὅπου μέν ἐστι δημόσιον φρέαρ ἐντὸς ἱππικοῦ, χρῆσθαι τούτῳ: τὸ δ' ἱππικὸν διάστημα τεσσάρων ἦν σταδίων: ὅπου δὲ πλεῖον ἀπέχει, ζητεῖν ὕδωρ ἴδιον: ἐὰν δὲ ὀρύξαντες ὀργυιῶν δέκα βάθος παρ' ἑαυτοῖς μὴ εὕρωσι, τότε λαμβάνειν παρὰ τοῦ γείτονος ἑξάχουν ὑδρίαν δὶς ἑκάστης ἡμέρας πληροῦντας: ἀπορίᾳ γὰρ ᾤετο δεῖν βοηθεῖν, οὐκ ἀργίαν ἐφοδιάζειν*
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> *Since the area is not sufficiently supplied with water, either from continuous flow rivers, or lakes or rich springs, but most people used artificial wells,* [Solon] *made a law, that, where there was a public well within a hippicon, that is, four stadia* [4 furlongs, 710 m]*, all should use that; but when it was farther off, they should try and procure water of their own; and if they had dug ten fathoms* [18.3 m] *deep and could find no water, they had liberty to fetch a hydria [pitcher] of six choae* [20 litres] *twice a day from their neighbours; for he thought it prudent to make provision against need, but not to supply laziness*
>
> *(Plutarch, Solon, 23).*

- Appropriate institutions completed the legislation framework and facilitated its implementation. A distinguished public administrator, called «κρουνῶν ἐπιμελητής» (Superintendent of Fountains) was appointed to operate and maintain the city's water system, to monitor enforcement of the regulations and to ensure the fair distribution of water. From Aristotle (Athenaion Politeia, 43.1) we learn that this officer was one of the few that were elected by vote whereas most other officers were chosen by lot; an interpretation is that this position was particularly important within the governance system of Athens.

Water problems in modern Greece

It seems unbelievable that in the initial stage of the development of the modern-day Athens as capital of the Greek state the water infrastructure was built upon that inherited from the antiquity. One of the oldest aqueducts is still in operation, 2.5 thousand years after its construction, providing irrigation water to the National Garden in the centre of Athens. The Hadrianean aqueduct used to provide drinking water up to the mid-twentieth century; currently research is under way investigating the possibility of rehabilitating it and putting it again into operation.

Over its long history, Greece has passed several phases with alternating long periods of ascend and decay, and shorter periods of peaks and crises. Naturally, Athens reflected those developments through history. One of the major crises in the contemporary history was the Asia Minor Catastrophe (ethnic cleansing) in 1922. Instantly, almost 250 000 refugees moved from Asia Minor to the wider Athens region, which corresponded to half of the then population of the city. The urban water system based on the ancient infrastructure was no longer sufficient and in the following years a new system started to develop, with the first project being a dam and reservoir in Marathon, built and operated by an American company (Ulen). After civil war (1945–1949) which followed the World War II, rapid and uncontrollable urbanization continued, as a result of new waves of settlers arriving in Athens for political and economic reasons. Thus, in the 1950s a new project bringing water from a nearby lake (Hylike) was added. The increase of the population of Athens and the development of higher living standards demanded the construction of a new project comprising a new dam (Mornos) and a 180 km long aqueduct, in operation since 1980. After a long and persistent drought, which started in the end of 1980s and lasted seven years, a new dam and reservoir (Evinos) were constructed. The thus formed complex and sophisticated water supply system of modern Athens provides water to the Athenians with sufficient quantity, very good quality and high reliability.

It is interesting that the modern system was the response of the people and authorities to several crises, civilian and natural. It is noteworthy that during the last natural crisis, the seven-year drought, the actions of the system manager (EYDAP) and the population reactions were so effective that no interruption of water supply or other type of severe problem occurred. During the current economic crisis in Greece, which afflicts Athens more dramatically than any other part of the country, no problem in the water supply system was encountered, while the water remains very cheap and EYDAP is economically robust. The only problem is that international private interests, perhaps charmed by the elaborate and reliable water supply system and looking for opportunities for profitable investments, exercise political pressure for privatization of the water services.

However, in other areas in Greece the situation in water resources development and management is very negative, totally different from that in the Athens water supply. About 2/3 of the countries hydropower potential has yet to be developed, while in the last decades only small progress has been seen in this respect. The most impressive negative example is the Mesochora project, a power plant in the Upper Acheloos River with installed capacity 170 MW and energy potential of 340 GWh/year. The dam and the hydropower plant have been constructed (an investment of 500 M€) and have been, in effect, ready for use since 2001. However, they have not been put into operation, thus causing a loss of 25 M€/year to the national economy (see Koutsoyiannis, 2011). This totally irrational situation has been the most representative example of a course that led Greece to the current financial crisis. It manifests the apathy of the Greek society with respect to exploiting national natural sources combined with a culture of greed that had to be satisfied by external loans. It further reflects the influence of the interests of private energy companies which oppose large-scale hydropower projects as their operation pushes

energy prices down during water-rich periods. All this is disguised with the garment of "green" or environmental ideology.

The Mesochora project has been designed as part of a bigger multi-purpose water project, the Acheloos-Thessaly project, which, in addition to power production, would transfer water the biggest plain of Greece, the Thessaly plain, whose water balance is negative. This would enhance agricultural production and even mitigate the negative environmental impacts in Thessaly due to water overexploitation. The project has been under construction for more than 25 years (since 1988), but it cannot be completed. Greek and European "greens" have fanatically fought the project. A web search for Acheloos crime would reveal that the project is regarded as a crime against the environment. Even a virtual "trial of Acheloos" was organized in 1996 by Greenpeace, WWF and three other "green" NGOs. Actual trials in the Supreme Court thwarted the government's plans several times, and the government had to repeatedly change the project design studies to comply with the court directives.

Even worse, in the last three decades, with the exception of the wrecking Acheloos-Thessaly project, no other large water project was planned or constructed to support agricultural development in Greece, where the climatic conditions necessitate irrigated agriculture. Instead, Greek and European governance encouraged a subsidy-based life of farmers which destroyed agricultural production and led Greece, traditionally an agricultural country, to become counterproductive in this respect and import agricultural products from other countries, including European ones which in addition export industrial products to Greece (Koutsoyiannis, 2011).

International setting of obstacles in solving modern water problems

Agricultural and industrial products are not the only ones imported to Greece. The "green" ideology which has fanatically opposed water resources development (as well as other types of development) is also imported in Greece from developed European countries and the USA. In those developed countries environmentalism did not cause serious damages as it did not affect the already built technological infrastructures. For example Germany and France have developed 100% and 97%, respectively, of their economically feasible hydropower potential. However, in Greece, where only 1/3 of this potential has been materialized, the obstruction of the development had destructive consequences (Koutsoyiannis, 2011). The eagerness of the Greek society to adopt European stereotypes and ideological doctrines and to mimic behaviours developed in other much richer countries would be comical if it was not tragic, as the current crisis shows.

However the environmentalist ideology and the related doctrines and stereotypes may be harmful per se even for the developed world, as they signify a departure from rational inquiry and from the problem-solving approach that was dominant up to the 20th century. According to this approach, engineering solutions to real world problems had a prominent position. By modifying the natural environment using engineering means, societies benefited substantially. This allowed increase of the population and its wealth, better quality of life, more hygienic life style and, most importantly, spectacularly increased

life expectation. Toward the end of the 20th century, as the infrastructures were completed to a large extent in the developed world, engineering started to lose importance and engineering solutions to existing problems were opposed, while virtual reality games gained the interest of the societies in the developed world. Environmentalism became the dominant ideological current and promoted a duty to save the planet from diverse threats, thus also determining the social views of water related problems and solutions. Most of these views are regarded "politically correct", but this "correctness" may be a euphemism, if not a synonym for irrationality.

Interestingly, while this ideology grew in the richest countries, it tried to influence the less developed world. This particularly concerns the dilemmas on water resources development and the questions about the appropriate scale of development in areas of the world not already developed. Certainly, the negative (and the positive) experiences from the already developed areas should be taken into account in exploring the opportunities and directions in less developed areas. However, just applying currently dominant ideological views, developed by people who live in the luxury of advanced (and in effect not questioned) infrastructure, brings in mind a land owner who, after building his villa, inhibits the neighbours to build in their own lands, which he regards as an extension of his garden (Koutsoyiannis, 2011).

The hypocrisy behind the promotion of this ideology is illustrated by the discussions that dam removal has significant environmental benefits for restoration of aquatic ecosystems and native fisheries. While the discussions are intensifying, what happens in reality diverges. An internet search will gather information from multiple sources that hundreds of dams have already been dismantled in an attempt to restore the health and vitality of rivers. However, more careful examination of specific data or photos of "dams removed" will reveal that these are small and rather old constructions that could be rather called barrages or embankments (with heights from less than a metre to a few metres). Magnifying stories of embankment demolition (necessary due to aging of the constructions), while at the same time keeping the luxury provided by the advanced large-scale infrastructures, has provided a fictitious element of realism of the environmentalist ideology, which may be necessary for its conservation (Koutsoyiannis, 2011).

This promoted perspective for water management of 21st century has become known by the name "soft path" (Gleick, 2002, 2003). According to Gleick (2002), the soft path:

> *by investing in decentralized facilities, efficient technologies and policies, and human capital […] will seek to improve overall productivity rather than to find new sources of supply [and] will deliver water services that are matched to the needs of end users, on both local and community scales.*

This has been promoted as a contrasting alterative to engineering solutions to problems that rely on infrastructure development, which Gleick (2002) calls the hard path and criticizes for:

> *spawning ecologically damaging, socially intrusive and capital-intensive projects that fail to deliver their promised benefits.*

Interestingly, the groups that discourage building new water projects and promote their soft path, at the same time highlight projections on threats like bigger floods and droughts of greater duration due to climate change, as well as the need for adaptation to climate change. The soft path concept has become popular in several countries and international organizations (Brooks et al., 2009). Thus, it was argued that

> [some] *major shortcomings of conventional water management* [are] *avoided by using the 'soft path'*
>
> (Wagner, 2008—an UNESCO publication)

and that

> *the soft path opens new avenues for accessing capital*
>
> (Leflaive, 2008—an OECD publication).

On the other side, the concept was criticized by Stakhiv (2011) who found it wholly inadequate for the needs of most of the developing world and Koutsoyiannis (2014) who argued that engineering as a means of planned and sophisticated change is essential for progress and evolution.

It must be noted though, that some recent developments are encouraging as they do not comply with the 'soft path' approach. Specifically, the World Bank (2013) decided to re-engage in large-scale hydropower infrastructure after having withdrawn from it for the past two decades. The report of the World Bank (2013) highlights the fact that nearly 3/4 of potential hydropower resources in the developing world are yet to be realized, including more than 90% in Sub-Saharan Africa and about 70% in South Asia. The report now recognizes that for many countries, hydropower is the largest source of affordable renewable energy and that reservoir hydropower can pave the way for the later introduction of other forms of renewable energy. Furthermore it recognizes the unique ability of hydropower to instantly offset variability of other parts of the electric power system, as well as the potential for pumped storage to store, for example, wind power during periods of surplus. It is very positive that these unique abilities of hydropower (Koutsoyiannis et al., 2008, 2009; Koutsoyiannis, 2011) are now understood by the World Bank and this creates hopes that it may be understood by others too. While this strategic change of World Bank has been carefully assessed and reported by some groups (Appleyard, 2013), naturally it disappointed other groups (Bosshard, 2013).

In addition, the European Union (EU) seems to start re-examining its policy, particularly with respect to hydropower plants and their potential to increase the energy storage capacity. According to EU, a larger capacity to store energy would allow a higher penetration of renewable energies and would support the EU's efforts to reach its goal of 20% of energy from renewables by 2020 (ec.europa.eu/dgs/jrc/index.cfm?id=1410&obj_id=16750&dt_code=NWS; Gimeno-Gutiérrez and Lacal-Arántegui, 2013; Eurelectric, 2011).

Conclusions

Technological solutions to water problems have a long history and have been common even in prehistoric civilizations. The marriage of technology with science and philosophy, which began in ancient Greece, was an important advancement. Ancient Athens provides an illustrative example of how to deal with the limited water resources. Important elements of the advanced urban water model of ancient Athens were the system durability and sustainability, as well as the achievement of balance between:

- structural (e.g. aqueducts) and non-structural (legislation and institutions) measures in water management;
- public and private sector participation;
- large-scale (public) works and small-scale constructions (cisterns and wells).

While current urban water systems are undoubtedly technologically superior compared to ancient ones, the technological principles are not different in the two cases. Moreover, it is questionable whether there is any progress with respect to durability, sustainability and balance. Perhaps the most important achievement in the Ancient Greek civilization is the development of the rationalist approach (that based on "correct reasoning" or "ορθός λόγος") in decision making. Arguably, in present day approaches there is regression in this respect, including in water resource problems. The emphasis on "politically correct" decisions typically reflects the dominance of an irrational approach.

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