Review Article

Planning of applied research in water development projects in Peru

Abstract

Peru is a country rich in water; but, like the other countries of South America, the spatial distribution, the temporary regime and the problems of pollution cause the country to confront conflicts related to the availability, opportunity and quality of the resource. Therefore, this paper describes the lines and research proposals to confront the problems that occur in the different stages of water resources development projects. It describes the particularities of the resource, the components of the exploitation projects and the different aspects that must be investigated to optimize the use of water within a sustainable framework.

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Introduction

Water is the most abundant substance in nature, is the main constituent of all living beings and is an important force that modifies the earth's surface; it is a key factor for the progress of civilization. Nearly 96.5% of the planet's water is found in the oceans. If the earth were a uniform sphere, this amount would be enough to cover it to a depth of about 2.6 kilometers; of the rest, 1.7% is in the polar ice caps, 1.7% in underground springs and only 0.1% in the surface and atmospheric water systems. Two thirds of the fresh water is polar ice and the rest is groundwater that goes from 200 to 600 meters deep. Most of the underground water below this depth is saline. Only 0.006% of fresh water is in the rivers. The biological water fixed in the tissues of plants and animals, represents about 0.003% of all fresh water, equivalent to half of the water contained in the rivers.[1,2] Peru is a country rich in water, but the spatial distribution, the temporary regime and pollution problems make the country confront conflicts related to the availability, opportunity and quality of the resource. Therefore, it is necessary to undertake lines of research to analyze the problems mentioned in the different stages of water resources development projects and find solutions to this problem. This paper describes the particularities of the resource, the components of the projects and the different aspects that must be investigated to optimize the use of water within a framework of sustainable development.

The hydrological cycle and the mythical conception of water

The water cycle comprises four parts:

a. The sea

b. To a minimum extent, the vegetation cover

c. Atmospheric water: water vapor and clouds (transfer, condensation, precipitation)

d. The superficial continental water (rivers, lakes) and subterranean water that ends up returning to the sea after a more or less long time, except for the fossil waters.

For millennia, humanity has considered water as a non-modifiable element of the globe, like air; and in antiquity, in an essentially rural world, water was greatly disconnected from economic circuits since the source, the river, the well and the cistern fed the populations without any cost or very low, depending on the servile condition or not of the workforce. Water was a gift from the gods. The aversion to modify the cycle of nature is evident even in the ancient Romans and city dwellers in particular. So they turned the mills night and day and fed giant fountains and hot springs. The nautical games needed the creation of specific circuses, the naumaquias. The historian Pierre Grimal calls Rome "the city of water", since eleven important aqueducts fed the city at the end of the empire. But, already to the 144 before J.C., the technique of the inverted siphons was dominated thanks to the use of conduits of lead, abundant metal in present-day Spain. According to bibliographical sources, the available water transported per inhabitant reached in Rome approximately 1000liters/day under the rule of Trajan (98-117 after J.C.). But this evaluation does not take into account huge leaks and losses of the old network. Fall Rome, then Constantinople, the taste for the fountains, for the water games and the hot springs is perpetuated and perfected in the Arab and Persian world, before penetrating again in Europe in the Baroque period. However, the fashion of thermalism only really took place in the eighteenth century and especially in the nineteenth century, with the rediscovery of the body and the cult of hygiene. Marienbad, Vichy, Baden-Baden, Spa, Bath and Montecatini flourished. In France, the Empress Eugenia promoted by her example the spas. Guy de Maupassant realistically describes in "Mont-Oriol" (1887), the birth of a thermal city in the countryside.[3,4] Water was a gift from the gods as the source tree or holy tree of the Canary Islands, which captured water from the mist until 1610 and fed the pre-Columbian populations of the island of Hierro.[5] For the Incas, Lake Titicaca was the center of the original world. In Aztec Mexico, Tlaloc was the god of rain. Symbolized by a frog or a frog, it was the divinity of the peasants. In fact, water was the essential factor in the stability and organization of the pre-Columbian peoples of Mexico. Finally, in the new world, around 1730, the coming of rain was still a divine phenomenon for Bartolomeo Arzáns, chronicler of Potosí, the largest American city of the seventeenth century.[6]

Water as a danger and source of conflict

One of the sources of danger and conflicts of water are the diseases of parasitic, bacterial and viral origin related to water that is much expanded. Man propagates them by poor hygiene or by erroneous behavior in front of water. The parasitosis of water origin dominates very much the pathology of the inhabitants of the third world: malaria (1 million deaths per year, 100 to 150 million cases per year, corresponding 90% to Africa, and 300 million carriers of parasites), sistosomiasis (300 million people at risk), filariasis, etc. Among the bacteria, the cholera vibrio is still the most infamous in Europe because of the pandemic of 1854 (about 150,000 deaths in France). In the nineteenth and twentieth centuries, seven global pandemics caused the deaths of hundreds of thousands of people. Among viruses, hepatitis A is like cholera, a disease of dirty hands and contaminated water. To this entourage, we must add the dysenteries of parasitic, bacterial and viral origin very serious in the newborn. Among the historical risks of water are the great rains and historical floods; thus, the eight humid 1313-20 years affected all of Europe and produced in 1315-16 one of the worst famines of the Middle Ages. In Winchester, England, the hay did not dry anymore, the crops were ridiculous, the oxen lost their four horseshoes, the eels spread outside the ponds, etc. The price of grain reached three times the average calculated for the period 1270-1350. The number of deaths was not exceeded by the great plague of 1349. Beside natural calamities, the misuse of soils multiplies landslides and triggers erosion, especially in arid and semi-arid mountainous areas. But water has also served as a point of support for civilizations. Since ancient times, water control implied power in the Middle East, where it is particularly rare. The historian Wittfogel could speak of "hydraulic" civilizations based on the ownership and mastery of water management. The Egyptian, Assyrian and Sabaean civilizations are obvious examples of this. They flourished in environments that became sensibly as arid as they are today.

In the 8th century BC, the "quanats" - underground artificial channels that transport water over long distances - were invented by the inhabitants of Urartu in present-day Turkey. This exploitation of the waters, generally arising from the drainage of aquifers, will spread in Persia, Egypt, India, Greece, the Maghreb, where it is known as "foggaras", in the Canaries: the galleries, etc.[7] Dan Gill proposes a scenario based on the Old Testament, in which the taking of Jerusalem by King David would have been done by taking the underground conduits of the city, fed by the waters of the Gihon fountain. However, the most obvious case of the importance of water was the fall of the kingdom of Saba, symbolically attributed to the destruction of the only dam of Marib (around the third century after J.C.). In the Surata of the flies of the Koran, the impiety of the inhabitants of that kingdom made it disappear because of water, the same element that had allowed its prosperity.[8] Even today, Israel carefully monitors its water supply and only a powerful interconnected network is able to meet its needs. The Palestinian entity will quickly face the lack of water and, therefore, its dependence on the Hebrew state. Other well-known contemporary cases are those of the international rivers where the countries located upstream can control the flows of those located downstream. Egypt depends on the political situation in Ethiopia, the true water castle of the Nile, a country whose reservoirs and future intakes could render the Aswan dam and its irrigated agriculture obsolete. Roman law considered running water as a common thing and, therefore, the rivers of continuous flow and its banks were outside trade. In the feudal system, political-military power was always limited by rural communities, who considered water as a common good whose incessant renovation prevented the seigneurial appropriation. In France, the royal power by the Edict of the Mills of 1566 declared that part of the domain of the crown was formed by all the rivers and tributaries that carried ships; except for fishing rights, mills, barges and other uses that individual could have as possession. Water has been a source of irrigation in the world. The aridity of the soil retards and prevents the germination of the seed and the development of the plants; therefore, in places where rains are scarce, or in those in which the rainfall regime is not suitable for planting, the irrigation of the land is the only solution to maintain the productivity of the soil.

The science of irrigation is not limited to the application of water to the soil, but includes the entire process from the basin to the plot and from there to the drainage channel. Irrigation experts are concerned with the study of water sources, currents, their distribution and regulation, and the drainage problems that these irrigation practices imply. Throughout its history, civilization has been influenced by the evolution of irrigation. But water is also a victim of pollution. The pollution caused by man is essentially chemistry; but also physical, organic and thermal. Among the chemical pollutants are the heavy metals, with the massive use of pesticides, since 1885 in the vineyard with the "Bordeaux soup" (liquid based on copper sulphate for the protection of the vineyard). More recently, nitrates are introduced into water, by intensification of livestock and excessive fertilization in rich countries or by the lack of good latrines in third world cities. Also, for a short time, phosphorus has become a problem for the quality of stagnant water because it enriches excessively or deoxygenates, with the over-abundant fertilization of soils and the generalization of the direct drainage of water evacuated from houses. Paradoxically, the progress of individual hygiene and the use of phosphate detergents produced a pollutant that also affects the seas, such as the Adriatic, with spectacular and nauseating green tides.[9–13] Heavy metals are very controlled, since the diseases they cause are all the more dangerous the more they concentrate on the biological chain. Let's cite the lead (maximum threshold tolerated by the current European standard 0.05mg/l) with lead poisoning, an intoxication very widespread in Roman antiquity when the water conduits were of this metal. We can also cite mercury (0.001mg/l tolerated) with Minamata disease, from the name of the Japanese locality where this disease wreaked havoc after the Second World War, affecting men and cats that ate contaminated fish. But, since the 16th century, mercury constantly pollutes the rivers and waters of the Andes, especially around mining operations. The introduction of this chemical element in the metallurgy of silver, in 1572, initiates the formidable wealth of Potosí. Although built at an altitude of 4000meters and isolated in the Andes, the city had more than 150,000 inhabitants between 1610 and 1650, that is, approximately the same population as Paris at that time. Dozens of mills and factories installed in the course of the Ribera de Vera Cruz crushed the silver ore, at the beginning of the seventeenth century, to amalgamate it with mercury. Now, the old and the new silver ore scoriae are still licked by the arroyos of the high lands until the Pilcomayo, while the pollution caused by the mercury has sharpened downstream of the gold deposits in the rivers that descend towards the Bolivian, Peruvian and Brazilian Amazon. Intermingled in this historical account of the relationship between water and man are the lines of research that must be undertaken to avoid or solve the problems that emerge in the use of water resources.

The need for environmental ethics in the use of water and research on water resources

Water, like air, is legally considered as a non-alienable common good. In some countries, however, this resource is privately owned and its possession is subject to certain rights of ownership or preference, creating ethical problems, although fortunately, the use is regulated,

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especially in terms of quality support and mitigation of the negative effects on the other resources of the basin derived from a bad use of water. For this reason, it has been considered convenient to include in this work the ethical and legal aspects related to the use of water. The content is based fundamentally on Guevara.[11,12]

Natural use of water

From the philosophical point of view, the natural, just or ethical concepts of water could be seen as a naturalistic fallacy, since Hume and Moore know that natural behavior has no connection with what is right or wrong, that is, there is no difference between fair use and natural use of water. If we accept that rivers and currents are not moral agents, it is even more difficult to establish the connection between ethical use and natural use, which forces swimming upstream against natural law and philosophy.

Events and actions are natural in several ways, which require differentiation:

a. In the sense of natural laws, the natural comprises all those events in which cause-effect relationships operate. Living organisms, among which man is included, use water in the natural sense, by drinking and deriving it, transporting it, using it for different uses. Instead of breaking, the laws are being used in our biology, engineering, agriculture and industry, in a natural way; the use may be fair, unfair, economic or uneconomical, but always natural

b. The spontaneous events of nature are natural; instead, the effects of human activities, intentional or not, are artificial (not natural). A fall of water is natural, a reservoir is not; the first occurs as a consequence of a natural law; the second is a deliberate action of man on the natural environment. A dike built by a beaver is natural because it responds to an instinctive attitude of the animal. Because the actions of man interrupt the spontaneity of nature, it is impossible for his works to be both deliberate and natural at the same time; certainly all water developments are not natural. Therefore, deliberate and at the same time natural use, is a contradiction of terms from the legal, philosophical and scientific points of view. If we had to choose between two terms, perhaps the most appropriate would be inevitable use and impossible use

c. The sense of the natural is relative, that is, some human interventions are more natural than others, depending on the degree of how they adjust to nature. Whichever paint is used to protect a water supply tank is unnatural, but the green color appears to be more natural than red. Any manufactured product is unnatural, but those that are biodegradable are more natural. Any use of water for irrigation is not natural, but water derived from a channel to a meadow is more natural than pumping fossil water from the depths of the subsoil. In this way we begin to observe a relevant sense about the natural use of water, only that at the same time a compatibility between the patterns of human consumption and the hydrological cycle or the ecological environment is required

d. Human actions violate natural laws. The laws of health, for example, operate in that sense; that is, that a natural law can be broken in favor of welfare. Then, it could be asserted that one does not act with ethics when the breaking of the law results in harm to oneself or to others. The laws of health elaborated by the jurists must be compatible with those discovered by the doctors; similarly, legislation on the use of water must be compatible with those of the ecosystem, discovered by biologists. Therefore, if in such use the hydrological, meteorological and ecological relationships are ignored, the use will be unnatural. Certainly a water policy that breaks the natural law is not desirable, much less one that breaks the laws of health; only that the laws of health are internal, while those of the health of the ecosystem operate on the environment, from the outside

e. Air, light, soil and water are the basic elements of existence; we can expand the list with photosynthesis, the acid cycle, the DNA code, etc. The man uses the first three in a natural way: we breathe the air, we take the heat from the sun, we sow in the ground, on which the solar energy acts and the rain falls. The water is the fourth indispensable element and there should be something that indicates that its use is also natural: being the indispensable water, without it there is simply no life, consequently, its use must be natural

f. Soil and water are elements that can be transferred in property rights; on the other hand, there is no property right for sunlight and for air. At least for three of the elements there are strict environmental regulations, such as the Clean Air Act, the Clear Water Act and the Soil Management and Conservation Act, all in the USA. Furthermore, man is already beginning to worry about the effects of the poor treatment of the ozone layer on the regime of solar illumination and global climate changes

g. The water we use follows a cycle in nature, which is why we worry that water legislation may be unnatural. In the strict sense, the use of water is biological, however neither the doctrine of preference existing in some countries nor the subsequent economic transformations pay attention to that fact. Although water is a natural resource, the prefix re means that the use is at least partially non-natural, that is, directed differently to those events through which nature allows the use of its sources. Man derives the waters from the natural causes towards the cities, towards the irrigation fields, towards the industries, etc.; considering such uses as natural, provided they do not go beyond the coverage of vital needs. Otherwise, as in the case of oil or iron, the use of water will be unnatural, as when we use it for the production of products or for the cooling of power generation plants. This is what happens with the use of air for the extraction of nitrogen, or sunlight for the production of energy by solar cells

h. Perhaps one could say that the use of water is natural when it is biological or ecological and cultural, otherwise, no. The connection of the natural and the ethical is clearer when it comes to biological and ecological needs. By using water vitally, it is being used ethically and at the same time respecting the integrity of the ecosystem.

Archaic use of water

The doctrine of the right of preference or lordship to justify its existence has coined the term of beneficial use, as a mixture of the ethical, the natural and the social; the first owner is required to make a beneficial use (includes vital biological, cultural and monetary use). But beneficial means archaic, because the logic is: if the right is older, it is better; that is to say that between competing uses, the preferential or header right dominates; whoever used the water first has the right of preference. If first, then more natural?, more ethical?. Right of preference has a clear legal content here, that is the law. Could the right of preference also have a moral content? or some biological or ecosystemic content ?. In the past, when the availability

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of water resources exceeded demands, the right of preference of seniors over juniors was not a problem. Currently, when uses are highly competitive, the manor does not allow access to surpluses, forcing the negotiation of rights and making the right of preference based on criteria of possession and need for stability of property rights and rapacity of current users who, when taking possession of the resource, did not consider the right of previous possession. The first Europeans who arrived to all parts of the globe claimed the discovery of the resources and claimed their possession (without taking into account the previous system of property rights) establishing the right of preference. Natural resources are not discovered, they are there and they should not be taken on property. Then another argument would be that of property in the sense of adequacy, not of belonging, which gives rise to the appropriate use of water; that is, that seniors can exercise their right of preference over the use of water, only while it is not against the vital interests of junior users or the ecosystem, for the benefit of future generations. This last aspect is consistent with the universally recognized water use priorities, in the following order: domestic, agricultural, industrial, other uses.

Economic use of water

The preemptive rights can be transferred by inheritance and then negotiated, converting said rights into not entirely moral facts, since the concept of water is passed as a preferential right to the concept of water as a commodity. The flow is no longer towards seniors, but towards money. There is no reason to think that the right of preference determines the use, that right has been washed and now use is determined by economic power. Control passes from the senior to the rich; that is to say, the economic forces prevail over the historical ones, passing from the archaic use to the economic use of water. Economical here does not mean efficient. Now, if before we were not sure that the right of preference was ethical, much less we are with respect to economic use. Although everyone can do what they want with their money, even acquire the right of preference for the use of water, but such use can not be to the detriment of the rights of others, that is, the proper use of the Water. In the strict sense of the natural, you do not pay for water but for the infrastructure implemented for its use, that is, you pay for water once it enters the distribution system. In connection with this we have the fact that normally the projects of hydraulic exploitation are very expensive to be financed by a person. Normally the funding sources are public or community; in those cases, the payment for the use or service is made by the Water Authority to amortize the capital used in the works; the water is still free, it is not left to the free market, it is paid for the service. In this modality, political and social criteria predominate.

Eco-systemic use of water

Ecology and ecosystem have the same root: oikos = house, they have to do with logic, the law of the home. Culturally, water is part of the home, we need it domestically, in agriculture and industrially; but first it is part of the home in a natural way. We are part of a community that includes soil, water, plants, animals, or collectively, ecosystem. This is probably the reason why the cultural use of water is free, as is air or sunlight. This is what constitutes the systemic eco-use of water, which also includes the reserves of scenic channels that can not be used. Using water ecosystematically the integrity, stability and beauty of the biotic community is preserved.

Unnatural use of water

Non-natural uses are those that are not desirable because they cause damage to the environment. There are several uses of water that are considered unnatural or inadequate:

a. When the soil is destroyed when using water
b. When, through use, the sustainability of the resource is lost, such as the pumping of fossil, non-renewable groundwater
c. When in the plans of use, the political limits ignore the hydrological limits. The political and hydrological divisions do not always coincide, but climatology, hydrology and meteorology are so important in planning the use of water resources, such as politics and socioeconomy. Conflicts of interest are created when political boundaries do not coincide with natural limits. Maybe that’s why, rival and river have the same root: rivus, because those who drink from the same stream often find themselves as competitors
d. Transfers are considered as unnatural uses, especially when they are made at undesirable scales for the source basin, when the transfers can destroy the possibilities of development of this at the expense of the receiving basin. Therefore, in the planning of the use of water, the urban developments that depend on the transfers for their supply must be avoided. On a regional scale, would it be better to move people to places with water availability than to move the water?
e. The bombardment of clouds to create artificial rain is considered equally unnatural, at least until the effects on global climate changes are known exactly. Climatic changes through the use of the latest technology is not an ecological harmony, it is an ecological arrogance
f. Increased runoff through forest management is also considered unnatural use of water. Efforts may be justified, but the effects unknown, especially after obtaining the desired increase. The risks, now unknown, are being transferred to future generations. Ecologically the system is being modified instead of seeking an adaptation and coexistence with it
g. Water uses that degrade its quality are considered unnatural. Some water laws only consider quantity, they ignore quality. It is not natural to affect biological life with sources of pollution such as irrigation return waters, wastewater in population and industrial developments
h. Non-natural uses of water are those that endanger endangered species and those that degrade the habitat of wildlife
i. The unnatural use of water is undoubtedly in contradiction with development and it is not going to stop, so it would be better to say that it is necessary to promote the use of water as natural as possible, avoiding it to flow uphill, towards money, against the law of gravity. In other words, we favor the preservation of the integrity, stability and beauty of the ecosystem.

From the considerations made on environmental ethics and the use of water, a series of research lines related to water resources are also revealed.

Situation of water resources in peru

The management of water resources in Peru presents different realities in its three main geographical zones: the coast, the highlands and the Amazon. The coast, developed and densely populated, but dry, has large hydraulic infrastructures and a viable institutional framework for integrated water management. The mountain range, with abundant water resources, has little infrastructure, a large part of its population is poor, and its institutions for water management are generally traditional in nature. The Peruvian Amazon, with the lowest density of population and infrastructure in the country, covers half of the Peruvian territory and gives birth to the Amazon River. At present, the Government is carrying out an important transformation in the management of its water resources, previously focused on the development of irrigation in the coastal zone. The objective is an integrated management of water resources at the basin level that includes the entire country, not just the coast. Despite important advances, such as the creation of the National Water Authority, several challenges remain, such as:

i. Increased water stress in the coastal region
ii. Lack of institutional capacity
iii. Deterioration of water quality
iv. Little efficiency in the irrigation sector
v. Inadequate supply of drinking water and sanitation.

History of water resources management and recent developments

During the last century, the Peruvian government has been the highest authority in the management of water resources and the main investor in hydraulic infrastructure. The hydraulic development, traditionally focused on the construction of infrastructure such as dams and irrigation to meet the growing water demand of a growing population and agriculture sector, especially on the coast. For example, in the 1950s and 1960s, the San Lorenzo and Tinajones dams, the largest in Peru, were built in the northern region. In the 70s, continued development of hydraulic infrastructure on the coast (MINAG). In the zones of the highlands and the Amazon, water resources have traditionally been managed through informal associations of users, the irrigation committees, which control the rudimentary hydraulic infrastructures. The Peruvian government has had little presence in the area, as well as state or international investments. Thus, at the beginning of the 21st century, Peru has a coastal zone with numerous hydraulic infrastructure controlled by structured and developed Users' Boards. In the highlands and the Amazon, with lands of scattered crops and less than one hectare, the implementation of User Boards is a process still being implemented. Irrigation committees continue to be an important actor in the management of water resources.

Surface and underground water resources

Peru has a large amount of water resources, with 106 basins and a per capita availability of 68,321m^3 in 2006, well above the average for South America, 45,399m^3. According to FAO[14] estimates, the long-term annual rainfall average is 1,738 m. There is considerable seasonal variability in river runoff, with two-thirds occurring between January and April. In addition, Peru concentrates 71% of the tropical glaciers of the Central Andes. The Andes divide Peru into three natural drainage basins: the Pacific basin, with 279,689km^2; Atlantic basin with 956, 751km^2; and Lake Titicaca basin with 48,775km^2.[14–16] According to data from ANA[15] the dry Pacific basin, with 37.4km^3 available per year, represents 1.8% of Peru's renewable water resources. Its 53 rivers, which flow westward from the Andes, supply most of the water in the coastal region. Only about 30% of these rivers are perennial. From 1984 to 2000, the average availability of water decreased to 33 million m^3; and from 2003 to 2004, to 20million m^3. The extraction for agriculture represents 14million m^3 (or 80% of the total use of water) and for domestic consumption, 2million m^3 (12% of the total). The Atlantic basin contains 97% of all available water and receives almost 2,000km^3 of rainfall per year. Agriculture also accounts for 80% of water use while domestic consumption is 14%. The Lake Titicaca basin receives 10km^3. In this basin, the agricultural use of water represents 66%, while domestic consumption is 30% shows in Table 1.

Table 1 key characteristic of drainage basins

Basin	Population (%)	Water availability (km^3)	per capita water availability (m^3)	Water use in agriculture (%)
Pacific	70	37,4	2.027	53
Atlantic	26	1.998,7	291.703	32
Titicaca Sea	4	10,1	9.715	13
Total	100	2.046,3	77.534	98

Source: ANA[16]

Different external tributaries contribute about 125km^3 per year to the Amazon River, in the Atlantic basin. The main tributaries are Napo, Tigre, Pastaza, Santiago, Morona, Cenepa and Chinchipe. According to figures from the National Institute of Natural Resources INRENA, the total amount of groundwater available on the coast varies between 35 and 40km^3. There are specific data only about eight coastal valleys, with 9km^3 of groundwater available. Approximately 1.8km^3 are currently extracted on the coast. There is not enough information on the availability and extraction of groundwater in the highland and Amazon regions[14] in Table 2.

Table 2 Extraction of groundwater by sectors in the peruvian coast

Sector	Water extraction in millons of m^3	Water extraction in %
Urban	367,0	19,9
Agriculture	911,0	49,5
Industrial	553,0	30,1

Source: ANA[16]

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Storage capacity and infrastructure

In 1980, the National Institute of Natural Resources of Peru (INRENA) established an inventory of Peru's water storage capacity, including lakes and dams. Peru has 12,201 lakes, of which 3,896 are in the Pacific basin, 7,441 in the Atlantic basin, 841 in the Titicaca basin and 23 in the closed Huarmicocha basin. INRENA reports that 186 lakes are used with a total capacity of 3km^3 and 342 lakes with a total capacity of 3.9km^3 are without any intervention. Currently, the largest number of lakes used are in the Pacific basin, with 105 lakes and a total capacity of 1.3km^3, followed by the Atlantic basin with 76 lakes and a capacity of 1.6km^3. Peru has 23 reservoirs with a total capacity of 1.9 km^3 and has sufficient geographic conditions to build some 238 reservoirs with a total capacity of 44km^3. The Pacific basin has 21 reservoirs with a total capacity of 1.8km^3; the Atlantic basin has 2 reservoirs with a capacity of 0.06km^3. The largest reservoirs are Poechos with a capacity of 1km^3, Tinajones with 0.32km^3, San Lorenzo with 0.25km^3 and El Fraile with 0.20km^3; all in the coastal region. (INRENA).

Water quality

The gradual decrease in water quality in Peru is due to untreated discharges, especially from the illegal mining industry (small-scale mining) and environmental liabilities, but also from municipalities and agriculture. Of the 53 rivers in the coastal zone, 16 are partially contaminated with lead, manganese and iron (mainly by illegal mining) and threaten irrigation and increase the cost of drinking water supply to coastal cities. Specifically, Ministery of Agriculkture of Peru considers the quality of the Moche, Santa, Mantaro, Chillón, Rimac, Tambo and Chili rivers to be "alarming". In addition, the 18 mining facilities located along the Mantaro River discharge untreated water into the main stream, threatening the water supply of the country's largest hydroelectric plant. Inefficient irrigation systems have generated problems of salinization and drainage in 300,000 ha of the coastal valleys (of a total irrigated area of 736,000 hectares), endangering the productivity of these lands. Drainage problems also affect 150,000 ha of the Amazon region. In the altiplano and Amazon zones, excessive deforestation produced by nomadic farming practices is causing erosion and soil degradation. In the mountains, between 55 and 60% of the earth is affected by this problem which increases the transport of substances downstream.

Management of water resources by sector

Drinking water and sanitation: Domestic consumption in Peru represents 7% of water withdrawal. The water and sanitation sector in Peru has made considerable progress over the past two decades, including increasing access to water from 30% to 62% between 1980 and 2004. Access to sanitation also increased from 9% to 30 % from 1985 to 2004. Progress has also been made in the disinfection of drinking water and wastewater treatment.

Despite these advances, water and sanitation services in Peru are characterized by low coverage and quality of service, as well as by the precarious financial situation of their suppliers. This, together with the lack of incentives to improve the management of the sector, has reduced investments to a minimum level, which is affecting the sustainability of supply.

Irrigation and drainage: Approximately 80% of the water extraction in Peru is used for irrigation; however, most of the water (70%) is lost due to the dependence on inefficient irrigation systems shows in Table 3.

Table 3 Area with irrigation infrastructure and irrigated areas (in thousands of hectares)

Region	Infrastructure (a)	%	Irrigation (b)	%	(b/a)
Costa	1.19	68	736	66	61
Sierra	453	26	289	26	63
Selva	109	6	84	8	77
Total	1.752	100	1.109	100	

Source: ANA[16]

Hydropower: In 2006, 72% of Peru's total electricity generation (27.4TWh) came from hydroelectric plants with conventional thermal plants that only operated during periods of peak demand or when hydroelectric production was restricted by meteorological phenomena. Hydropower represents 48% of the total installed capacity. The extraction of non-potable water for hydroelectric generation represents 11,138million m³ per year. The largest hydroelectric facility in the country is the 900 MW Mantaro complex in southern Peru, operated by the state company ELECTROPERÚ. The two hydroelectric plants in the complex generate more than a third of Peru's total electricity supply.

Aquatic ecosystems: In Peru there are 12,201 lakes and lagoons, of which 3,896 are in the Pacific basin, 7,441 in the Atlantic basin, 841 in the Titicaca basin and 23 in the Huarmicocha system. There are also approximately 5 million ha of wetlands and 4500 ha of mangroves. The wetlands of Peru play an important role for rural communities. These wetlands are the source of animal and totora proteins, a plant that is used in the artisanal production of boats and floating elements. Estuaries are also essential for the reproduction of several basic marine species for the fishing industry. Other uses, such as industrial algae production and bird watching tourism, have not yet been fully developed. In 1996, the government implemented a National Strategy for the Conservation of Wetlands with the objective of increasing the amount of mangroves, swamps, estuaries and lagoons considered protected areas. Uncertainty about land ownership, industrial pollution, urban growth and deforestation continue to threaten the integrity of Peruvian wetlands. The Pucchún lagoon in Arequipa, of 5,000 ha, has been completely dried for agricultural purposes. The *Pantanos de Villa*, located south of Lima, were reduced from the original 5,000 hectares to 300 hectares in 1989 as a result of the urban growth of the city of Lima. When analyzing the situation of water resources in Peru, it is observed that this aspect constitutes a well-paid field for research.

Planning and applied research on water resources in peru

The planning of projects of hydraulic utilization is carried out in several stages. From the definition of single-purpose or uni-sectorial projects, the consideration is given to those with multiple or multisectoral purposes and that of Integral projects. The latter are formulated as instruments for the organization of large areas of regional development, based on the water resource and the development strategies defined in the national plans for these areas and in the policies and strategies of water resources management. The hydraulic projects are framed within a broad context of territorial ordering in accordance with the guidelines on the matter dictated by the pertinent instance, aspects that also demand investigation oriented to the solution of problems. They begin with the construction of land reclamation works, that is, works for the regulation or control of river beds, drainage, viability and conservation of the basin. Land reclamation pursues as a fundamental task the execution of a program of exploitation of wide territorial coverage. As part of the integral development hydraulic projects, the construction of wells and lagoons, the works for the consolidation of already constructed irrigation systems, the infrastructure for small irrigation systems, the reservoirs for multiple purposes and the works of rehabilitation of the basins. The planning of hydraulic works is very complex. It usually happens that the solution of problems that in a first examination seem very clear; it is seen later, when a more detailed investigation is carried out, which depends on the previous solution of other more fundamental problems. For example, it is not uncommon for a water catchment area to require the construction of terraces as a means of combating surface run-off, and that, at the same time, it is impossible to build such terraces until some means of transport has been found. Rationalization of a land ownership regime based on excessive parcelling. Similarly, in some areas, the need for forestry reforestation is evident, but such reforestation will not be successful until some changes are introduced in traditional grazing servitudes in these areas. It also often happens that an aspect of the development of a reception basin depends on what is done in other places. The capacity of accumulation of water with which the reservoirs are projected will depend partially on the measures adopted to combat erosion in the land of the catchment area. The plans for the regulation of grazing depend on the possibility of having another source of fodder for the animals. All these aspects of the improvement of watersheds are interrelated, and careful planning is necessary if the works are to succeed. It is not easy to draw a line between planning and project. In general, planning refers to the formulation of decisions as to what should be done, and the project to the way in which it should be done. From the point of view of the Engineering, the project usually refers to the planning of the structures in detail as a guide for those commissioned to build them. The same can be applied to other aspects of a river basin improvement program, using the term "Project" to designate the planning of all the details of a practical program. However, it is more usual to use the term "Work Plan", in relation to those aspects of the works other than the structure project. Project is the set of studies and basic data that serve to define an exploitation for the use, control or conservation of the concomitant hydraulic and natural resources of a basin, and that allow estimating the advantages and disadvantages for the nation, which derive from assigning certain economic resources to initiate or improve the production of certain goods and services. In relation to hydraulic works, river basins are linked to flood control, irrigation, drinking water and electric power production, navigation, soil conservation, recreation and, in end, of all those works in some way related to the use, control and conservation of water resources, which are included within the concept "Environmental Systems".[17,18]

Stages in the planning of environmental systems

Project research or "recognition": the objectives of meeting the needs of the area are established through the optimal use of hydraulic resources and concomitantly, through the use of rational technology from the engineering point of view, it is also carried out in this phase, a rapid inventory of all resources, especially human, hydraulic, soil and forest resources, and the basic information of a hydrological, agrological, geological, topographic, socioeconomic and environmental impact, which allows for an diagnosis of the regional problem.

Project at pre-investment level: it includes two stages: profile or preliminary project and feasibility or final project. The profile concludes the inventory of all existing resources in the basin and carries out detailed studies of hydrological, topographic and socio-economic, and semi-detailed geology and agrology to determine the technical feasibility of the system of use. The structure defined in the study of recognition is dimensioned. In the feasibility or final project, the structural and hydraulic calculation of the different works is carried out and construction plans are drawn up.

Investment-level project: In this stage the specifications of each one of the components of the system are prepared and the construction, operation and maintenance programs and the environmental impacts of each phase are elaborated.

Economic Evaluation: Once the projects have been finalized, they are evaluated economically, estimating the social costs, the direct benefits of the project and the indirect and intangible benefits induced by the project, as well as the costs of mitigation measures of the environmental impacts. Below is a guide to the activities required for the development of Environmental Systems, which are sources of research lines oriented to solve problems:

i. Edaphology: Semidetached studies of soil in the exploitation area and its taxonomic classification and capacity of use
ii. Hydrology: Information necessary to determine the most suitable type of use for the project
iii. Information and Climatological and Hydrological Studies: quality and quantity of the water resource to be used in the project; appropriate information for the location and design of the project works; basic information for other studies (agro-economic, drainage, hydrographic, erosion and sedimentation, fluvial

Components of an environmental system of water use

"Integral project" is considered to be one that meets the demand for all possible uses, that is, flood mitigation, irrigation and drainage, electric power generation, navigation and supply to populations and industry. It consists of the following elements that can be considered hydraulically independent.[18]

i. Reservoir with their related works (intake and spillway): the regulation of the water regime of the river.
ii. Diversion works: they replace the reservoir when the minimum flow of the river is sufficient to supply the demand
iii. Driving works: transport water from the reservoir site or bypass to the delivery site
iv. Distribution and sanitation works: they deliver the water to each one of the users (distribution network for supply), agricultural parcels in the irrigation. The sanitation works are responsible for eliminating the surplus after use in supplies and maintain
v. Protective and conservation works: hydraulic structures to protect the areas surrounding the bed of the maximum floods; set of measures that are adopted in the entire extension of the basin (especially in the upper parts) to avoid the loss of soil by erosion and the consequent problems caused by the transport of sediments
vi. Evaluation of environmental impacts and mitigation works: Impact of all works and mitigation measures for those impacts.

The activities that can be developed to innovate in the improvement of each component of the harvesting systems constitute lines of research orientes to the solutiuon of problems.

Research and management of water resources

Based on the policy guidelines for integrated water management, the sustainability of the resource is considered, with the purpose of meeting the social and economic requirements of development in terms of quantity, quality, and spatial and temporal distribution. It is necessary a National Environmental Plan that defines a series of strategies including scientific and technological knowledge in a comprehensive manner to establish behavior, quality, availability, use requirements, as well as the progress and appropriation of technology, essential tools for the assertive management, adjusting to the reality of the country. Other strategies must also be considered, such as concertation where water is a vital and determining element of the dynamics of societies; education as a basis in the construction of water culture, graduality with the purpose of prioritizing in regional, local and national contexts to achieve goals; citizen participation and decentralized administration. Therefore, lines of research should be established addressing issues of application such as hydrometeorological information processing, capturing, treatment and distribution of water to cover the different demands, urban cleaning, wastewater and related activities. In addition, the products and services for the defense and protection of the environment, the evaluation of alternatives for wastewater, wastewater treatment and management of water resources, the purification of water, the study of the various sources of water supply, the integrated management of watersheds, the study of lakes, the modeling of hydrosystems and the modeling of water quality.

General Objective of the investigation

Investigate, study, generate and implement tools that allow to know and manage water resources within environmental sustainability strategies, which affects the harmony between what nature offers and what is consumed.

Specific research objectives

a. Diagnose the situation of water resources, advancing studies that allow the optimization of processes and the hydraulic component; the design and simulation or modeling of hydraulic processes and phenomena, including pilot or laboratory scale studies; as well as, the inclusion of biotechnologies in research related to water resources

b. Identify problems in the inadequate management of resources, for example in aspects related to water supply systems for different uses and the generation of liquid discharges

c. Venture into the field of research related to the configuration, design, construction and evaluation of supply systems, control and treatment of drinking water and domestic waste

d. Evaluate the alternatives for drinking water and wastewater treatment, as well as Water Resources Management, Wastewater Treatment

e. Carry out municipal diagnoses in sewer systems, characterization of discharges and validation of analytical techniques, carry out studies of wastewater treatment

f. Establish treatment alternatives at the level of pre-design, design, supervision, startup and evaluation of this type of treatment systems

g. Carry out diagnostics and assessment analysis of the different departmental supply systems, analysis of public health problems generated by the poor quality of drinking water, evaluation and management of supply sources, technical operational analysis and evaluation of water treatment systems and of aqueducts

h. Apply computational tools in the solution of problems related to water resources

i. Investigate aspects of maintenance and improvement in the efficiency of the use of water resources on which survival and human development depend

j. Investigate the interrelation of technical, social, economic, political and normative aspects, guide the process of administering a water resource as an element of development of a community

k. Strengthen, from applied and formative research in the environmental field, the relationship between higher education centers, public institutions and companies

l. Generate alternative solutions to the problems that companies present in terms of use of natural resources, consumption, generation of waste, emissions, generation of waste, among others

m. Potentiate the concept of environmental performance at the business level and promote the use of methodologies that allow the company to evaluate and propose improvements regarding its environmental management

n. Generate participation spaces for civil, agricultural, environmental engineering programs, from the research, in the planning and ordering of the territory

o. Strengthen the use of the environmental variable when guiding guidelines for the planning of the territory are being developed

p. Promote the use of environmental assessment methodologies in urban and rural planning processes, regional.

Justification

The management of water resources implies a dynamic process, of continuous validation of the various stages involved, the pre-established policies, must be preceded by a diagnosis, to contemplate clearly defined objectives and priorities, and must establish the design of legal, administrative instruments, economic and investment, among others, that guide the formulation and development of programs to fully comply with the objectives. Within the national consensus on the administration of water resources, the definition of supply and demand and balance is considered as a conceptual framework, which should be one of the guidelines for research on water resources. The Constitution of the Republic of Peru of 1993 establishes foundations based on the rights and duties of citizens and the competence of public bodies in terms of conservation, defense and improvement of the environment. It is important to highlight the responsibility that each individual has with the environment, indicating that all activities likely to cause damage to ecosystems must be previously accompanied by environmental and socio-cultural impact studies. Water Resources Law aims to establish the provisions governing the integral management of water as an essential element for life,

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human wellbeing and sustainable development of the country and is of a strategic nature and State interest. Most of the municipalities of the country collect domestic wastewater and rainwater in combined sewage systems, to be subsequently discharged at different points in the environment without any treatment, on the soils or on the water sources that circulate through the municipality in different senses, bringing this as a consequence the deterioration in the quality of resources, impact of biota, negative impacts on the landscape, sedimentation in the channels of water sources and decrease of their transport capacity, floods in low areas, generation of vectors and foci of infection. The problem can increase when talking about industrial corridors from which multiplicity of liquid waste is generated with qualities that bring serious problems on the environment and the health of people.

Additionally, the Declaration of the United Nations (UN) on the human right to water and sanitation can be cited: Deeply concerned that approximately 884 million people lack access to drinking water and more than 2,600 million people do not have access to basic sanitation, and alarmed because approximately 1.5 million children under the age of 5 die each year and 443 million school days are lost as a result of diseases related to water and sanitation:

i. Declares the right to safe drinking water and sanitation as an essential human right for the full enjoyment of life and all human rights;
ii. Calls upon States and international organizations to provide financial resources and support capacity-building and technology transfer through international assistance and cooperation, in particular to developing countries, in order to intensify efforts for providing the entire population with affordable access to drinking water and sanitation;
iii. Welcomes the decision of the Human Rights Council to request the Independent Expert on the issue of Human Rights Obligations Related to Access to Drinking Water and Sanitation to submit an annual report to the General Assembly, and encourages the independent expert to continue working on all aspects of its mandate and, in consultation with all relevant United Nations agencies, funds and programs, include in the report submitted to the Assembly at its sixty-sixth session the main difficulties related to the realization of the human right to clean and safe water and sanitation, and the effect of these on the achievement of the Millennium Development Goals.

Due to the posed situation, there is a need to develop research processes aimed at the technical and economic solution to this problem, which can be supported in the evaluation of systems at laboratory or pilot scale and in which the real conditions that a community and its surrounding environment can experience as a result of controlled discharges of liquid effluents.

Lines of research in water resources

Why organize research/training of human resources around lines, programs and projects?: Due to the need to make the transition from the knowledge obtained in books in university with professional orientation where teaching is transmitting and schooled, to the knowledge obtained through lines of research developed by teachers/researchers/students in university with scientific orientation, where teaching is based on research.[19]

What are the tools of articulation, linkage and integration?:

i. Diagnosis of scientific research in higher education and research centers
ii. Formulation of problems- projects- programs
iii. Formulation of lines of research/training of human resources/extension

Definition of research lines

i. Common sense approach: channels or streams through which the investigation in an organization runs; map that guides scientific research according to the vision and mission of the institution in which the research is carried out
ii. Technical-scientific approach to the line of research category: Systematic deepening in the knowledge of a problematic field that deserves to be studied in depth. The lines become a tool to do science and must have a priority rating according to the national development guidelines
iii. The research lines are not decreed: they are revealed, they are discovered, they are tracked, and they are inferred, from the research processes completed or in execution in an organization
iv. Strategies to define the lines of research in an organization: dialogue, participation and interaction, among the relevant actors.

Genealogy of a line of research

i. A research problem scientifically relevant and socially relevant
ii. Availability of researchers / group of researchers
iii. A research process to advance in the resolution of the problem (programs/projects): resources; costs; equipment; theoretical and methodological underpinnings; results.
iv. Refraction of the process towards the environment and other scientific problems: intra- and extra-scientific relevance
v. Interactions with other researchers and other research lines.

Consolidated research lines

a. Research agents: institutes; centers; units; programs; chairs; laboratories.
b. Products or achievements: research results or progress; reports; books; Scientific work; procedures; patents; technological innovations.

Formulation of a research project

i. Proposal or precise statement of the problema
ii. General and specific objectives of the investigation
iii. Main hypothesis with which work will be done in the investigation
iv. Methods or strategies that will be applied in the execution of the investigation
v. Importance of the investigation
vi. Schedule of activities
vii. Research unit to which the project, the line and the program are ascribed
viii. Project financing entity.

Strategies for problem solving and creativity in research

i. Motivation

ii. Definition of the problem (identification)

iii. Exploration (analysis)

iv. Plan to solve the problema (generation of alternatives)

v. Development (selection of alternatives and implementation)

vi. Verification (control) and feedback

vii. Generalization (application)

Research lines in water resources

The components/issues of the project given above can be used to take advantage of water resources (environmental system) and in the analysis of information:

i. Reservoirs with their related works (intake and spillway)

ii. Derivation works

iii. Driving works

iv. Distribution and sanitation works

v. Protection and conservation works

vi. Evaluation of environmental impacts and mitigation works

vii. Hydrometeorological, hydrogeological, geotechnical, hydraulic studies, etc.

The research proposal

The research proposal is the map that will guide the researcher to develop their research, optimizing time and resources. The proposal consists of the following elements:

a. **The title**: The function of the title is to summarize the main idea, it must be short and written in style for publication purposes. In the title, you must identify the technical aspect on which you are going to investigate and / or analyze, indicating the variables or the model or method to be applied.

b. **The approach of the problem**: Initially a presentation should be included that briefly indicates the content to be treated in this section. It is advisable to use the strategy "from the general to the particular"; that is, presenting first the problem on which the research at global level will be treated; then at the national, regional and local levels; finally, by way of closure, the overall purpose of the investigation is indicated.

c. **The justification**: This section identifies the reasons for the usefulness of the work; that is, what will be the benefits derived from the research to be carried out. For this, criteria such as: social relevance; convenience and benefits; practical implications; theoric value; methodological implications and others.

d. **The General and Specific Objectives**: The objectives constitute the guide that directs the research process that prevent deviating from the fundamental purpose or what is intended to be done. The general objective has a close relationship with the title of the investigation; it specifies the global action to be carried out, so that once the general objective is defined, the most appropriate title can be formulated. On the other hand, the specific objectives imply separate, different and congruent actions that in a logical sequence lead to the purpose of the investigation.

e. **Theoretical or referential framework**: It includes a bibliographic review or state of the art of the previous works carried out on the problem under study and the contextual reality in which it is located, at least during the last five years. In this phase, the concepts and terms related to the problem under study are usually explained. The theoretical framework or referential framework fulfills functions as helps prevent mistakes that have been made in other studies; guidance on the form of how the study will be carried out; broadens the horizon and guides the researcher to focus on his problem, avoiding deviations from the original approach; inspires new lines and areas of research; and provide a framework for interpreting the results of the study. The following are the constitutive elements of the referential theoretical framework: general considerations; background of the investigation; historical background: organizational review; theoretical bases or theoretical foundations; variable system; legal bases; and definition of basic terms.

f. **Methodological framework:** This section presents a set of ordered steps that will allow obtaining, classifying, understanding and organizing information to provide feasible solutions. The methodology is the strategy with which the study will be conducted and is proposed by activities, where each of them corresponds to one or more objectives; it also includes the application of techniques, methods and procedures which must be expressed in sufficient detail.

g. **Schedule of activities**: This phase constitutes a Gantt diagram type scheme in which the activities of a project are scheduled and related and the probable time for its realization. This allows to organize the actions and coordinate the activities of a certain stage. It is recommended to use the month as a time scale.

h. **Budget and institutional support**: It is the determined function and destined to ensure the timely availability of the human, material and financial resources necessary for the realization of the project.

i. **Bibliographical references**: This phase has as its primary objective to offer the reader all the necessary information about the different sources used. All documents consulted, books, degree works, articles, scientists must be placed directly whatever their nature: printed or electronic. It is a list of reference sources used as direct support to prepare the proposal. It is not a bibliography on the subject. It is recommended to use a reference system, for example APA, and to maintain it throughout the drafting of the proposal and the research report.[20]

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Conflict of interest

The author declares there is no conflict of interest.

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