Environmental Flow Policy Analysis for the Tempisque River, Costa Rica: Employing Stakeholder Driven Data Collection to Inform Water Management Decisions

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Introduction

The Tempisque-Bebedero River Basin is located in the Guanacaste Region of northwestern Costa Rica. Dependence on water resources is a persistent trait of this seasonally dry region. The two principle rivers, the Tempisque and Bebedero, flow through many diverse ecosystems from their headwaters, high in the volcanic mountains, through the swamps of the Palo Verde National Park to the Gulf of Nicoya. These rivers delineate the eastern (Bebedero River) and western (Tempisque River) boundaries of the Palo Verde National Park. This science and policy analysis will specifically focus on the Tempisque River Basin.

The Palo Verde wetlands were designated as a site of international importance under the Ramsar convention because they provide habitat for diverse flora and fauna such as fish and migratory birds. The Gulf of Nicoya provides 90% of all of the fish for consumption in Costa Rica.[1] Thus, protection of the ecological systems in the Basin is an important water management objective. Tourism, aquaculture, rice and sugar cane productions drive the economy of this basin and significantly contribute to the economy of Costa Rica.[2] In the year 2000, agricultural land uses occupied 25% of the land in the Tempisque Basin.[3] The future of water resource sustainability in the Tempisque River Basin is dependent upon finding a balance between societal water needs (such as irrigation and flood management) and ecological requirements (such as minimum flows and water levels).

Establishing environmental flows has been proposed as a method to delineate minimum criteria to preserve ecological health, while simultaneously allowing water resource consumption for society.[4] Environmental flows is defined as "the quantity and quality of water expressed in

[1] Jorge Arturo Jiménez Ramon et al., *Perspectives for the Integrated Management of the Tempisque River Basin*, at 6-7, Organization for Tropical Studies (2001).
[2] *Id*, at VII.
[3] Jorge A. Jiménez Ramon et al., *Conceptualization of Environmental Flow in Costa Rica: Preliminary Determination for the Tempisque River,* at 4, San Jose, Costa Rica: UICN- Union Mudial para la Naturalea, Oficinia Regional Para Mesoamerica (2005).
[4] *Id*.

terms of magnitude, duration, seasonality and frequency of flows required to maintain a desired level of health in the system."[5] The hydrology of most watersheds in Costa Rica has been altered, changing the quality, quantity, and patterns of flow. Many riparian communities have experienced deforestation, and land-use has transformed from forest to farms.[6] In this context, the environmental flow has relevance as a tool to determine the amount of water required to maintain healthy ecosystems.

Three questions are essential to this analysis.

- Are the proposed environmental flows adequate for maintaining the ecological integrity of the Tempisque River?
- What changes in the legal/policy framework are necessary to implement an environmental flow?
- What tools can be developed to enhance understanding of the system?

This analysis will examine the environmental flow methodology proposed by Jimenez et al. (2005) in the context of other environmental flow methods, analyze the current socio-political framework in which this methodology would be applied, perform a stakeholder analysis to determine the interests the various stakeholders have in effective water resource management, and recommend further actions to help contribute to a more holistic management of water resources.

Background

Water Resources Management

Surface water is used extensively within the Tempisque Basin. The principle flow contributions in the Basin are from precipitation in the watershed, return flows from the Arenal-Tempisque Irrigation District (PRAT) and groundwater. As water flows through the basin it is used multiple times for hydropower, agriculture, and aquaculture before it discharges to the Gulf of Nicoya. Over 40% of the total annual flow of the Tempisque River is under concession.[7] However, water-use estimates have considerable uncertainty due to the prevalence of unauthorized diversions and poor knowledge of ecosystem demand for water.[8] Almost 72% of the water flow occurs during the rain season (June to November).[9] This distribution of rainfall contributes to floods in the wet season and periods of little or no flow during the dry season.[10] Annual and semi-annual floods, although detrimental to the agriculture and aquaculture industries, are essential for replenishment of nutrient rich sediments for wetlands in the Tempisque Basin floodplain. Additionally, they allow for the distribution of seeds and eggs, which in turn allow for the distribution of species in the basin. Environmental flows should

[5] Ramon et al., *supra* note 3, at 4.
[6] *Id*, at 5.
[7] Yamileth Astorga Espeleta, *Water Management in Tempisque River Basin, Guanacaste, Costa Rica*, PowerPoint Presentation (July 2009).
[8] *Id*.
[9] *Id*.
[10] *Id*.

consider a minimum amount of flow as well as variation in flow regimes, such as low flows, seasonal highs, flood peaks, and extraordinary events.[11] The Palo Verde wetlands are sensitive to changes in the hydrology, and anthropogenic changes in hydrology are currently altering habitats.[12] Thus, restoring the character of the hydrology is an important objective of environmental flow determinations. Available river flow records for the basin are limited, with few stream gages, only monthly data records, and years of missing data.[13]

If there is flow in the river during the dry season, it is most likely from groundwater discharge from the aquifer to the stream or, to a lesser extent, return flows from the PRAT irrigation project. Therefore, groundwater likely plays an important role in environmental flows. Like the Tempisque River's resources, groundwater is an important resource for stakeholders in the basin. Often, groundwater is the only source of potable water for populations in the middle to lower Tempisque basin, including the larger population centers of Sardinal, Filadelfia, Belén, and Santa Cruz.[14] Over the last decade, the region experienced an estimated 93% increase in well construction. Currently, more than 9,886 estimated wells exist.[15] Many of those wells supply water for irrigation and municipal use. Adverse effects on groundwater availability results from impacts from the construction of illegal wells and from wells approved without any technical criteria. In addition, volumes of extracted groundwater and groundwater depths are poorly documented. Since 2005, it is well known that some aquifers, including the Tempisque,[16] in the coastal zones of the North Pacific have been over-exploited by extensive tourism development and agricultural production.[17] The water management comptroller (Contraloría General de la República) has requested the denial of new well permits; nonetheless, illegal well construction continues. Effective management of water resources requires more extensive knowledge of the concessions given to the various stakeholders in the basin, along with more precise data about the volumes of water use in order to balance water resources use for both human and ecological uses.[18]

Wetlands have shrunk more than 60% in the last thirty years due to drainage and construction of dikes for flood protection and irrigation.[19] Wetlands attenuate some effects of flooding and can help provide water to the river throughout the dry season. Parties are conducting studies to resolve long-term water needs for domestic consumption, irrigation, and tourism in the dry Pacific region of the country. One such study proposes the construction of two multi-purpose dams in the Piedras and Tempisque Rivers to increase the availability of rainwater

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[11] *Id*, at 4-5.

[12] Pérez-Castillo, A.G., *Evaluación de las Aguas de Drenaje del Sector de Tamarindo y su Influencia Sobre el Parque Nacional Palo Verde*, 26 Ciencia y Tecnología 71, at 72 (2010).

[13] INSTITUTO COSTARRICENSE DE ELECTRICIDAD, DETERMINACION DE UNA METOLODOGIA PARA ESTABLECER EL CAUDAL DE COMPENSACION EN LOS RIOS DE COSTA RICA A PARTIR DE DOS CASOS DE ESTUDIO, at 14, (2007).

[14] Arias Salguero et al., *Estado del Conocimiento del Agua Subterranea en Costa Rica*, 117 Boletin Geologico y Minero 63, at 68 (2006).

[15] *Id*.

[16] INSTITUTO COSTARRICENSE DE ELECTRICIDAD, *supra* note 13, at 9.

[17] *Id*, at 13.

[18] Ramon et al., *supra* note 3, at 14.

[19] *Id*.

and reduce pressure on groundwater.[20] Hydrologic variability is also an important part of environmental flow, and dams reduce the peak flow events, change the hydrologic regime, and alter habitats. As long as the proposed dams within the basin are not built, the environmental flow will maintain hydrologic variability, and thus peak flows of the hydrologic regime will occur and allow for replenishment of wetlands.[21]

Ecosystems That Depend on Environmental Flow

Ecological goods and services provided by freshwater systems have sustained human civilization for millennia. Increased understanding of natural ecological processes contribute to better ecosystem management and improves environmental and human conditions in many parts of the world.[22] Ecological population dynamics in areas surrounding rivers are complex and difficult to predict. However, direct modification of flow regimes, or indirect modifications through land use or land cover, are manifest in ecological responses.[23]

The fluvial-riparian habitat (stream corridor), is one of the most productive of all ecosystems. The stream corridor is a complex aquatic-biological continuum nourished by the bank and floodplain forest, and affected by management of the entire watershed. The riparian and fluvial continuum is essential to the maintenance of biodiversity in terrestrial ecosystems. Fragmentation and ecological discontinuity produced by human activities result in a visible impact on the riparian and stream systems. Such damages are apparent in a large part of Guanacaste's rivers and in Costa Rica's rivers in general.[24] Hydrologic alteration affects aquatic biota, in some cases eliminating species of fish and gastropods, and reduces biodiversity.[25]

There are several ways in which water flow affects ecology in riparian corridors.[26]

1. Water depth controls water temperature, which influences the amount of dissolved oxygen available for aquatic life.

2. The natural flow regime shapes the evolution, distribution, and stability of aquatic biota and ecological processes.

3. The flow regime affects the retention of sediments, organic matter, and pollutants that reach the river from surrounding areas.

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[20] Maureen Ballestero et al., *Groundwater in Central America: Its Importance, Development and Use, with Particular Reference to Its Role in Irrigated Agriculture*, at 14 [M. Girorodano & K.G. Vilholth, *Agricultural Groundwater Revolution; Opportunities and Threats to Development* (M. Girodano and K.G. Vilholth, CAB International (2007)].

[21] Ramon et al., *supra* note 3, at 32.

[22] Robert J. Naiman et al., *Legitimizing Fluvial Ecosystems as Users of Water: An Overview*, 30 Environmental Management 455, at 456 (2002).

[23] *Id*, at 457.

[24] G.W. Frankie et al., *Biodiversity Conservation in Costa Rica, Learning the Lessons in a Seasonal Dry Forest*, at 10 University of California Press (2004).

[25] Naiman et al., *supra* note 22, at 458.

[26] *Id*, at 458. Frankie et al., *supra* note 24, at 10. Ramon et al., *supra* note 3, at 6-7.

4. Changes in sedimentation driven by changes in flow regime can also alter riparian habitats.

5. Biophysical changes from changes in the hydrologic regime affect goods derived from these ecosystems (such as drinking water and fishery products).

Environmental Flow in the Tempisque

Environmental flows are needed to determine the extent to which water can be used without affecting the integrity of the riverine ecosystem.[27] Many methods have been proposed to determine environmental flows. Regardless of the method selected, an environmental flow must have three essential factors: specifications should be legally defensible, scientifically defensible, and administratively feasible.[28] Methodologies fall into four categories, namely hydraulic rating, historical flow record, habitat rating, and holistic methodologies. Hydraulic rating, historical flow record, and habitat rating methods were developed in order to analyze the requirements of individual species or assemblages of fish, and lack any consideration of riparian vegetation. Determining the most appropriate method depends upon the level of data and the intellectual capital required to use the data. As more data becomes available, parties can pursue more integrative methods to determine environmental flows, such as the Expert Panel and Habitat Analysis Methods, which employ panels of experts to look at the environmental flow in terms of hydrologic and geomorphological controls on habitat stability, riparian vegetation, and invertebrate, riparian, wetland, and marine ecology.[29]

The concept of environmental flow is new to Costa Rica. An arbitrarily established environmental flow set at 10% of natural stream flow was only recently implemented. Some governmental organizations have started to investigate more integrative methods in order to avoid this arbitrary establishment of the amount of flow.[30] The environmental flow proposed by Jimenez at al. (2005) might be considered a combination of the historical flow record and a simplified habitat rating methodology, and effectively uses of the limited data available to make assertions regarding the environmental flow regime that would protect several key species.

The wetted perimeter habitat rating methodology used by Jimenez et al. (2005) is limited to analyzing hydrologic and bathymetric data from the upper to middle Tempisque River. Jimenez et al. 2005 employed the HEC-RAS model to estimate stage in twenty-six surveyed river cross-sections to determine the sufficiency of depths for the habitat and breeding requirements of Crocodiles and Guapote fish. These species were selected because of the species' prevalence and the ease of using flow to define their habitat requirements. Due to stream flow data constraints (1 gage), analyses were only performed for the uppermost 49% of the Tempisque basin. Two periods of record were used in the analyses, one from 1951-1969 (pre-agriculture) and one from 1980-1999 (agriculture development). Statistical analyses were performed to determine if stream flow reductions could be attributed to agricultural withdrawals.

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[27] A. H. Arthington & J.M. Zalucki, *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Methods*, Land and Water Resources Research and Development Corporation (1998).

[28] Ramon et al, *supra* note 3 at 9.

[29] Arthington & Zalucki, *supra* note 27, at 53.

[30] INSTITUTO COSTARRICENSE DE ELECTRICIDAD, *supra* note 13. Julio C. Calvo Alvarado, *Determinación Preliminar del Caudal Ambiental en el Río Tempisque, Costa Rica: el Enfoque Hidrológico con Limitación de Datos*, 5 Revista Forestal 1 (2008).

Environmental flows were based on three thresholds derived from the stream flow record: normal environmental flow, minimum environmental flow, and maximum environmental flow. The method used assumes that the data adequately described the system and that protection of the two key species will protect the other species in the ecosystem.[31] The environmental flow determination for the Tempisque River could be improved by collection of additional data, such as finer temporal and spatial scale flow data, information about riparian plant species, and better records of actual diversions from the river and groundwater withdrawals.

Stakeholder Analysis

The following groups have been identified as key stakeholders: non-governmental organizations, the agriculture industry, both local and federal governments of Costa Rica, local populations, tourism operators, tourists, the fishing industry, and aquaculture.

Non-governmental organizations are primarily concerned with the protection and conservation of natural resources and maintaining hydro-variation. The local agricultural community consists of both private individuals practicing subsistence farming and large scale industrial farms. Currently, the primary crops produced in the region are sugar cane, rice, and melon. Depending on the size and nature of the gardens or crops, the agricultural community seeks varying levels of water use, although united in their desire for a consistent supply. The agricultural community also recognizes the necessity of hydro-variability to sustain their crops. Both local and federal governments seek to meet the needs of their citizens by providing clean drinking water, establishing flood controls, while also deriving benefits from a robust agricultural industry. Relevant governmental bodies include the Instituto Costarricense de Acuenductos y Alcantarilladas (AyA), the Ministerio de Ambiente, Energía, y Telecomunicaciones (MINAET), Secretaría Técnica Nacional de Ambiente (SETENA), Servicio Nacional de Aguas Subterraneas, Riego y Avenamientos (SENARA), and the Ministerio de Salud Publica (MINSA).

Additionally, a number of other stakeholders exist in the local community. Approximately 170,000 people live within the watershed and depend on the river for domestic water consumption, irrigation, flood protection, agricultural use, and recreation.[32] Tourism operators share this interest, while simultaneously seeking to provide a consistent supply of potable water for their clients. As a result, the interests of tourism providers coincide with the interests of tourists, who desire safe water for drinking and bathing while on vacation. Roughly 90% of fish consumed in Costa Rica comes from the Gulf of Nicoya, at the mouth of the basin.[33] Members of the fishing community are interested in having a supply of non-polluted freshwater from the river as a means of maintaining a healthy and safe stock of wild fish. Further upstream, individuals in the aquaculture industry also seek to have a consistent supply of water to continue to produce fish.

[31] Arthington & Zalucki, *supra* note 27, at 53.
[32] Ramon et al., *supra* note 3, at 4.
[33] Ramon et al., *supra* note 1, at 6-7.

In general, data regarding stakeholders is extremely limited, and "[i]nformation needs with regards to social systems are even greater than natural system data needs."[34] Due to the rapidly shifting economic nature of the area, additional research is necessary to perform a thorough stakeholder analysis.

Legal and Policy Framework

Exploitation of Water & Balancing Interests through Water Governance

An effective policy framework governing environmental flows in the Tempisque River Basin requires balancing the interests of all stakeholders in the watershed. Thus, such a policy framework must afford appropriate weight to the needs (such as the requirements for development) of all affected stakeholders, while also simultaneously taking into consideration maintenance of the ecological environment. Determining the precise nature of both the needs of human consumption and ecological needs of water flow partially depends on the value stakeholders place on the effects of differing flow levels. However, these values may represent water flow levels unduly favoring certain parties at the expense of other parties. In areas such as the Tempisque River Basin the current condition of the river flow illustrates that parties have in fact failed to value a flow level appropriate for certain measurements of ecological health. As it applies to water resources in general, this balance between human consumption and ecological interests can be met where sustainable water resource management is the main objective of the policy framework.[35] The policies of most Latin American countries fail to facilitate this objective, as they favor private water rights over the effects these rights might cause on ecosystems.[36] In accordance with the policies found in most Latin American countries, the Costa Rican policy framework regulating water resource allocation in the Tempisque River basin also appears to inadequately consider the ecological effects of water rights for development purposes on ecosystems.

Although demand for water in the Tempisque River Basin is projected to continue to significantly increase in the near future, Jimenez et al. (2005) found that government authorities granted an excessive amount of concessions (rights to withdraw water) in the basin, as the concessions currently granted amount to a volume almost three times higher than the river's maximum flow. Addressing this over-exploitation of water resources through effective implementation and management of an environmental flows regime for the Tempisque River requires addressing excessive concessions through a policy framework governing water resource allocation on a basin-wide scale.[37] For any significant water basin, institutional coordination must characterize the basin-wide governing framework. Also, in order to balance development interests with ecological interests, and thus provide an effective environmental flows regime resulting in the decrease of the amount of water withdrawn, the policy framework relevant to water resource allocation must facilitate the integration of all stakeholders into the

[34] *Id*, at 20.
[35] Yesid Carvajal-Escobar, *Environmental Flow Regime in the Framework of Integrated Water Resources Management Strategy*, 8 Ecohydrology & Hydrology 307, at 310 (2008).
[36] *Id*, at 310.
[37] *See* Ramon et al., *supra* note 1.

decisionmaking process, while at the same time providing for certain regulatory norms. These regulatory norms must be designed to decrease the amount of water withdrawn in the basin when the value placed on environmental flows by stakeholders, and the resulting implementation of measures lacking ecological protection, fails to ensure certain characteristics of ecological health. Clearly, the current policy framework governing water use in both the Tempisque River Basin and Costa Rica in general fails to facilitate such a balance.

The Role of Governmental Entities

The Costa Rican state can be characterized as a highly centralized state. Although the Constitution of Costa Rica provides municipal governing bodies with the sole authority to govern the respective Costa Rican municipalities, these bodies lack the ability to exert meaningful influence due mainly to fiscal restraints.[38] Moreover, the Constitution fails to establish any governing authorities for the seven provinces into which Costa Rica is divided.[39] As a result of the lack of meaningful authority exercised by the local government bodies, autonomous institutions of the Costa Rican state government provide most of the public services in Costa Rica.[40]

The Instituto Costarricense de Electricidad (ICE) is organized to provide and manage energy development in Costa Rica, with a particular focus on energy from water resources. As their mandate relates to the development of energy, ICE is not involved in granting concessions.[41] However, due both to considerable political influence and to control over water resources as hydroelectric providers, ICE significantly affects water flows in the Tempisque River Basin, as well as in Costa Rica as a whole.[42] ICE can directly alter flows of water so long as they do so in furtherance of activities related to energy development.

When it comes to water resource allocation, MINAET holds primary administrative and management authority. With this authority MINAET is in charge of granting concessions for water use, yet a successful application for a concession within the Tempisque River Basin generally must satisfy two other criteria prior to the grant of a concession. First, SENARA must authorize groundwater concessions and concessions for irrigation. Second, SETENA must conduct a successful Environmental Impact Assessment.

As it relates to the PRAT project itself, SENARA is the main administrative body. In this capacity SENARA collects a fee from the agricultural producers in the area as payment for the service of water, and currently the fee is a fixed fee on a per hectare basis. This fixed fee, rather than a fee based on volume of water use, adds to the exploitation of water because the fee fails to incentivize efficient use of water.[43] Changing SENARA's fee collection structure to require

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[38] Maureen Ballestero, *Tárcoles River Basin Costa Rica (Background Paper)*, Agriculture and Rural Development Department at the World Bank, at 12 (2003).
[39] *Id*, at 12.
[40] *Id*, at 10.
[41] William Blomquist et al., *Institutional and Policy Analysis of River Basin Management: The Tárcoles River Basin, Costa Rica,* World Bank Policy Research Working Paper 3612, at 10 (2005).
[42] *Id*, at 10 & 20.
[43] *Id*, at 10.

agricultural producers to pay for the amount of water they use will help address the excessive use of water in the Tempisque River Basin.

A final relevant agency, AyA, has authority to manage water supply systems built after its creation in 1961. In this capacity AyA promulgates technical design requirements for both private and public drinking water systems. AyA also influences water resource allocation by virtue of their responsibility for issuing the final authorization for all construction, modification, or amplification of drinking water systems, thus prohibiting all other governmental entities from issuing a construction permit without the authorization of AyA. Also, where inadequate service of a water supply system results from municipal operation of the system, AyA can assume operational responsibility.[44]

Despite the fact that the regulation of water resource allocation is centralized in Costa Rican state institutions, these institutions currently fail, for various reasons, to adequately manage water resources, and also fail to protect environmental flows. The reasons for this failure mainly result from the fact that Costa Rican policy fails to direct the institutions in a way that integrates and coordinates their activities.[45]

The Water Law & the Proposed Water Law

Regulation of water resources in Costa Rica is currently based on the Costa Rican Water Law of 1942 (Ley de Aguas N. 276). This seventy year old law established a framework that has failed to facilitate an organized system for regulating water use.[46] The framework enabled the establishment of a suite of uncoordinated regulatory entities that have promulgated regulations based on their independent interests, without consideration of the activities of other governmental entities. In general, the system emerging from the framework created by the current Water Law fails to provide for the efficient use of water or for water conservation. Also, as it relates to water allocation, the Water Law causes problems in other ways. Most directly applicable to environmental flows, the water law fails to provide for a direct procedure to establish such flows, and thus the legislation fails to significantly consider the ecosystem as a user of water and the overall importance of environmental flows. Another allocation issue related to the Water Law relates to the Law's treatment of users of water existing before the Law's adoption. In particular, the law enabled users of water who began using the water before the adoption of the law to continue using the water, so long as the use did not restrict the flow of water in way that frustrated the needs of the land downstream. This right to continue to use water allowed an existing user to continue such use even if the illegal user was unable to prove the legality of obtaining the right to use the water. The Water Law also creates a hierarchy of priorities for uses, and MINAET prioritizes the uses listed higher when deciding between competing applicants for a particular concession. In many applications, this hierarchy is unsuited to contemporary circumstances due to a separate set of values in existence at the time the law was adopted. Additionally, when MINAET considers applications for concessions, the current Water Law only requires MINAET to find two criteria satisfied before granting a concession. Namely, these criteria require that the proposed use does not affect existing legal users and that

[44] *Id*, at 11.
[45] Ramon et al., *supra* note 3, at 3.
[46] Ballestero, *supra* note 38, at 29.

the proposed use avoids effects on public uses. Finally, under the current law, a concession grants the right to use water without any requirement that the amount of water used respond to the time of year, and thus the concession grants the right to use the same amount of water in the dry season as the wet season.[47]

A new water law, the Ley De Recurso Hídrico, has been proposed by Costa Rica's Legislative Assembly. This proposed law addresses many problems associated with the current policy framework governing water resource allocation in Costa Rica, and it significantly improves upon the current Water Law of 1942.[48] Thus, stakeholders interested in establishing environmental flows for the Tempisque River should advocate for the passage of this new law. Among a variety of proposed changes to Costa Rica's system of water law, the proposed Ley De Recurso Hídrico explicitly creates a procedure for establishing environmental flows. Also, as part of the determination of whether to grant a particular concession, the law calls for a consideration of both the reasonableness of the water use and the cumulative ecosystem impacts of the use.

The proposed law also facilitates institutional coordination. Although it provides for MINAET to continue to act as the main regulatory body for water regulation, the new law also places various entities within MINAET to coordinate regulatory activities on a basin-wide scale. The most significant new entity proposed for establishment within MINAET, the National Directorate of Water Resources, generally enjoys operational independence from MINAET, and engages in activities like planning for the management of water resources, investing in resources, and conducting studies to inform decisionmaking. Moreover, the new law enables increased coordination by including, in an advisory and monitoring role, institutes like ICE into MINAET's structure.

Other changes proposed by the new water law include decreasing the maximum duration of concessions to twenty years, as opposed to the current thirty year maximum, and requiring that a hierarchy of uses be determined by various councils created to oversee water management in particular hyrdologic units throughout Costa Rica. By placing the determination of priority of use into the hands of such councils, the priorities will be more applicable to the realities in the respective basins and to contemporary circumstances.

Filling Data Gaps through Citizen Driven Data Collection

Hydrological, chemical, and biological data about waterways is integral to establishing an environmental flow.[49] Lack of data has contributed to over-allocation; more than 20.5 m3/sec of water is under concession but the rivers flow is rarely over 7 m3/s during the dry season.[50]

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[47] Danielle Beland et al, *Good Practices for the Cultivation of Trout in Costa Rica*, at 14, Worchester Polythectic & Instituto Costarricense de Pesca y Acuicultura, Departamento de Acuicultura (2008).

[48] Viviana Cover-Ruiz et al., *El Pais Verde & the Sunshine State: A Comparative Analysis, Conclusions, and Recommendations for Costa Rica Water Allocation Reform*, at 19, Conservation Clinic, Uniiversity of Florida/University of Costa Rica (2009).

[49] Ramon et al., *supra* note 3, at 4.

[50] *Id*, at 13.

Restoring a minimum flow equal to the historical minimum flow means ending most of the current concessions, which is neither socially or economically feasible.[51] Data is needed to establish how concessions may need to be reallocated to allow for minimum ecological flows. In addition to data limitations on surface water, groundwater is not well understood. There are more than 1800 wells withdrawing water from Tempisque aquifers. Groundwater is used to cover the shortfall of surface water concessions. Currently no detailed study on use, availability and recharge capacity has been completed.[52] Increasing uncontrolled use of surface and groundwater poses a threat to the regions social, economic, and ecological integrity. Participation of stakeholders affected by an environmental flow determination is integral to effective implementation. Incorporation of a science based methodology for determining environmental flows is also needed to fill gaps in current knowledge of hydrology.

One way to overcome the limitations of the lack of hydrologic data in the Tempisque Basin is through the collection of Traditional Ecological Knowledge (TEK). TEK is defined as "all types of knowledge about the environment derived from experience and traditions of a particular group of people."[53] Examples of TEK include the collection of information about the incidence of certain plants near a river, requesting fishermen to report sightings of different species of fish, or administering surveys to local community members that relate to seasonal variations in flood levels.[54] The use of TEK is beneficial in a variety of ways: it encourages community participation in monitoring the watershed, it is inclusive of frequently marginalized stakeholders, it provides information regarding the cultural significance of the area that may be overlooked, and it aids in overcoming the limitations of scarce data.

TEK has inherent drawbacks, such as bias, inconsistency in methodology, and difficulty in developing interest in participation among community members. Many studies, however, demonstrate that TEK can provide comparably accurate data relative to professional scientific studies.[55] Additionally, certain steps may be taken to alleviate these concerns. Data can be presented to other community members as a means of soliciting a more complete perspective (an informal peer-editing process), and participants may also be screened and provided with training to encourage greater consistency and accuracy in methodology.[56] Ultimately, using TEK in conjunction with formal scientific studies has the potential to provide a more comprehensive knowledge-base regarding environmental flows in the Tempisque Basin.

As previously discussed, the availability of spatially and temporally distributed hydrological data is limited in the basin. Several simple methods could be deployed to gather additional hydrological and ecological data using TEK and citizen driven science. To monitor surface flows, specific measuring points in the river can be surveyed in places where possible to make relative river stage observations daily, and recorded by willing citizens living in the

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[51] *Id*, at 28.
[52] *Id*, at 12.
[53] P.J. Usher, *Traditional Ecological Knowledge in Environmental Assessment and Management*, 53 Arctic 183 (2000).
[54] Peter C. Esselman & Jeffrey J. Opperman, Overcoming Information Limitations for the Prescription of an Environmental Flow Regime for a Central American River, 15 Ecology & Society 6 (2010).
[55] *Id*.
[56] *Id*.

riparian areas. As an example of this type of monitoring, community members could measure daily stream stage using an installed measuring staff or color coded system. Additionally, if citizens performed the "leaf test", which consists of dropping a leaf in the river to measure the time it takes for the leaf to travel a specific distance, the test could provide rough information about the river velocity. When the river velocity measurement is combined with the surveyed cross-section data and stage data, a rough estimate of stream volume can be derived. While this methodology consists of a fair amount of uncertainty, it has the potential to provide general information, temporally and spatially distributed, related to volumes of water flow, and can be distributed where no data currently exists. If these citizen flow measurements were deployed along the river and well recorded, then the variation in volume from upstream and downstream users can infer relative water loss between users. Another example of easily-implemented citizen science is to request monitoring data from groundwater well users, such as depth to groundwater on a monthly time interval. These data can begin to fill in the immense data gaps in understanding of the groundwater system in the Tempisque Basin, which is a critical source of flow in the river during the dry season. Collecting and storing these data in a central database available to other users, could contribute greatly to the understanding of stakeholders within the basin.

Recommendations and Conclusions

The environmental flow methodology proposed by Jimenez et al. (2005) provides a good balance between human and ecological needs, making the most of limited available data. The proposed environmental flow preserves hydrologic variability while still allowing concessions for use. The following recommendations should be considered:

- More data should be collected about surface water diversions and groundwater use
- More data should be collected to characterize hydrologic variability in the system
- Enhance the environmental flow determination with more detailed modeling, more diverse ecological response data, and expert panels
- Incorporate more species in the environmental flow analysis
- Determine ways flow can be reallocated to allow for flow to remain in the system during the dry season

Passage of the Ley De Recurso Hídrico, the proposed water law, will go a long way towards addressing many of the problems inherent in the current political framework related both to water resource allocation in general and to establishing an appropriate environmental flow. Among a variety of changes to the current policy framework, this proposed law provides for increased planning and research activities by the relevant institutional entities. Moreover, the new law increases coordination among the various institutes by incorporating the support or advice of certain institutes into MINAET's decisionmaking process, and by creating new independent bodies within MINAET to make water allocation decisions. The new water law also provides for increased consideration of ecosystem needs by decreasing the maximum duration of concessions and by including an analysis of the impacts on ecosystems in the concession granting process. Finally, the new water law creates a framework where various councils

oversee water resource management at the scale of the hydrologic basin, thereby increasing value of the whole watershed ecosystem in the decisionmaking process. These councils also set standards for determining a hierarchy of priorities of uses, reflecting the values of the stakeholders of a particular basin.

As it relates to the availability of information used to set an appropriate environmental flow, TEK and Citizen Driven science may be able to fill the huge gaps in understanding of the system. By involving citizens in the process of data collection, more data can be collected. Collecting more data will contribute to a better understanding of seasonal and annual variation in groundwater and surface water hydrology. The following data collection programs are recommended:

- Stream flow data that includes stage, velocity, and discharge
- Stream channel cross sections to describe channel morphology
- Historical flow surveys
- Fish catch surveys
- Vegetation surveys
- Groundwater monitoring

In order to develop increased data related environmental flows in the Tempisque Basin, the use of Traditional Ecological Knowledge and Citizen Science should be encouraged in conjunction with greater scientific research. Passage of the new water law legislation will more effectively generate information from these sources. Ultimately, implementing any, or all, of these recommendations will aid in balancing the interests of stakeholders while maintaining the ecological integrity of the watershed.