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Martin Walter. Explaining the emergence of transboundary groundwater management : the cases of Guaran  aquifer system, the Hueco and Mesilla Bols n aquifers, and the G n vois aquifer. Political science. Institut d' tudes politiques de Paris - Sciences Po, 2012. English. NNT : 2012IEPP0023 . tel-03657598

HAL Id: tel-03657598

<https://sciencespo.hal.science/tel-03657598>

Submitted on 3 May 2022

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**Institut d'Etudes Politiques de Paris
ECOLE DOCTORALE DE SCIENCES PO
Programme doctoral Amérique Latine**

Centre d'études et de recherches internationales

Doctorat en Science Politique

Accord d'Echange avec Northwestern University

Explaining the Emergence of Transboundary Groundwater Management

*The Cases of Guaraní Aquifer System, the Hueco and
Mesilla Bolsón Aquifers, and the Génomais Aquifer*

Martin Walter

*Thèse dirigée par Olivier Dabène (Professeur des Universités à l'Institut
d'Etudes Politiques de Paris) et Hendrik Spruyt (Professeur à Northwestern
University)*

Soutenue le 17 décembre 2012

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L'émergence de la gestion des eaux souterraines transfrontalières

*Les cas du système aquifère Guaraní, les aquifères
Hueco et Mesilla Bolsón, et l'aquifère du Génévois*

GRAND RESUME

Martin Walter

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Grand Résumé

Existe-t-il des solutions fiables et durables aux problèmes provoqués par l'exploitation des ressources hydriques? Cette question est l'objet de recherches et de décisions de gestion depuis des siècles. Les enquêtes à ce sujet ont contribué à la formulation d'un vaste corpus qui décrit et explique les nombreux rôles joués par l'eau dans nos sociétés, ainsi que les facteurs qui déterminent la création et la mise en place de différentes approches pour la résolution des conflits découlant de l'utilisation des ressources. Ces contributions ont mis en évidence la nature multidimensionnelle des ressources en eau et la relation complexe entre le social et l'environnement. L'intérêt pour les ressources hydriques reflète le besoin d'eau pour la survie et pour le développement économique et social. Cependant, en dépit de la diversité des analyses de ces ressources et des expériences de gestion, un type particulier d'eau n'est entré que très récemment dans l'agenda politique international : cette recherche porte sur les «eaux invisibles» stockées dans des réservoirs souterrains naturels appelés aquifères.

Les eaux souterraines constituent environ 96 pourcent des réserves mondiales d'eau douce non-congelée, et entre vingt-cinq et quarante pourcent du total d'eau potable disponible au niveau global (Morris, Lawrence et al. 2003, Shiklomanov et Rodda 2003). Les eaux souterraines sont une composante essentielle dans l'approvisionnement des villes, de l'industrie et de l'agriculture. Leur exploitation crée des bénéfices économiques et sociaux importants. L'utilisation des eaux souterraines extrait des millions de personnes d'en-dessous du seuil de pauvreté et permet la croissance de régions autrement trop arides (Moench 2003, Stephan 2007, la CEE-ONU 2007). Pourtant, jusqu'à la dernière partie du XXe siècle, ces eaux ont été jugées trop «secrètes», «mystérieuses» et «occultes» pour justifier l'émergence d'initiatives de gestion (Eckstein 1995, Eckstein et Eckstein, 2005). En 2002, seulement vingt-sept pourcent de tous les accords internationaux portant sur des eaux internationales

mentionnait les eaux souterraines (Eckstein 1995, Matsumoto 2002, Jarvis, Giordano et al, 2005.), L'absence relative des mécanismes de gestion dédiés à ces ressources a conduit à des situations d'«anarchie colossale» et à la détérioration progressive et significative de ces ressources au niveau global (Krishna et Salman 1999).

Or, depuis la moitié du XXème, la reconnaissance des menaces découlant de la détérioration des eaux souterraines –liée à un intérêt politique et académique croissant envers ce genre de ressources– s'est développée d'une manière significative. La gestion des eaux souterraines est progressivement devenue un enjeu majeur dans les discussions sur la gouvernance de l'environnement. Le sujet est devenu le centre du débat dans une série de conférences internationales sur la gouvernance de l'eau, et il a été l'objet de plusieurs initiatives de gestion aux niveaux local, régional et international (Yamada 2004, l'UNESCO-PHI 2010). En ligne avec les recherches dédiées à la compréhension des défis posés par la gestion des ressources en eau et l'émergence de régulations pour la gestion de l'environnement, cette thèse examine l'émergence de mécanismes pour la gestion des eaux souterraines transfrontalières. Elle se propose d'apporter une réponse à une question apparemment simple : quels sont les facteurs qui déclenchent l'émergence et la mise en œuvre de mécanismes pour la gestion des eaux souterraines transfrontalières?

Les théories avancées suggèrent que la rareté relative des mécanismes de gestion des eaux souterraines transfrontalières résulte d'une compréhension insuffisante des ressources, dérivée de l'absence de symptômes évidents de détérioration des ressources, ou bien de la réticence ou même l'incompétence des acteurs politiques à faire face aux problèmes posés par les ressources. La littérature retient généralement que la gestion des eaux souterraines est une réponse rationnelle et fonctionnelle à des problèmes connus, aux menaces liées aux ressources, selon la volonté et les possibilités des puissants. Les théories coïncident généralement quant au fait que «le pouvoir est important», mais la littérature suppose

également que les connaissances scientifiques opèrent souvent comme une ressource au service des acteurs politiques, en tant qu'instrument qui permet de contraindre et de persuader les adversaires. Les connaissances peuvent fonctionner comme une arme pour contester la légitimité des institutions établies, déstabiliser les alliances politiques dominantes, et pour transformer les modes de gouvernance environnementale. En effet, indispensables à l'émergence de mécanismes rationnels de gouvernance environnementale, les connaissances sur les eaux souterraines facilitent non seulement l'exploitation des ressources mais aussi la compréhension des causes derrière la détérioration et l'épuisement des ressources, ainsi que l'identification des responsables et des mesures nécessaires pour assurer l'efficacité des actions visant à l'atténuation des problèmes. Ce travail examine les éléments qui déterminent l'émergence de connaissances sur les ressources et le rôle de ces connaissances dans l'élaboration des problèmes de politique environnementale, la conception et la mise en œuvre des mécanismes de gestion de l'environnement, ainsi que l'impact de différents régimes de gouvernance sur les ressources.

Les facteurs qui expliquent le mieux la réforme et l'émergence de mécanismes de gestion de l'eau font l'objet d'un vif débat. Dans la littérature, les chercheurs sont d'accord en général en ce que l'existence de problèmes associés aux ressources hydriques, réels ou potentiels, est fondamentale pour expliquer le développement des initiatives de gestion, mais aussi que l'existence des problèmes n'est pas suffisante pour expliquer la mise en œuvre de solutions de gestion. Compte tenu du rôle crucial de l'eau pour la survie et pour le développement, la gestion de ces ressources a été étudiée par la plupart, sinon par la totalité des disciplines sociales, voire de toutes, ce qui a conduit à la prolifération d'interprétations à la fois sur le sens et sur les variables analytiques qu'il convient de prendre en compte. Malgré le nombre et la diversité des contributions académiques sur l'étude des ressources hydriques, la majorité des recherches portent néanmoins sur la gestion des eaux de surface : les bassins fluviaux, les

lacs et les mers. L'émergence de mécanismes pour la gestion des eaux souterraines demeure ainsi largement sous-théorisée. Est-ce simplement parce que les théories disponibles sont applicables aux eaux souterraines? Avons-nous besoin de nouvelles théories compte tenu des particularités ontologiques propres aux eaux stockées dans les nappes phréatiques ?

Cette thèse avance l'hypothèse que la reconnaissance des problèmes des eaux souterraines est déterminée par trois facteurs : 1. l'utilisation des eaux souterraines, 2. les caractéristiques des ressources hydrogéologiques et, 3. la valorisation sociale des services éco-systémiques fournis par les ressources. Le premier facteur se réfère au niveau de l'exploitation des ressources, qui est déterminé par la demande sociale et les usages des eaux souterraines, ainsi que par la disponibilité de technologies pour l'extraction des ressources des aquifères. Le deuxième facteur se réfère aux connaissances hydrogéologiques sur la région dans laquelle a lieu l'exploitation des eaux souterraines –sur des caractéristiques de l'aquifère telles que sa capacité de stockage, les volumes de recharge et de décharge, la qualité naturelle des eaux souterraines et leur vulnérabilité aux perturbations anthropiques et non anthropiques. Le troisième facteur, la valeur sociale des services éco-systémiques fournis par les eaux souterraines, fait allusion à la valeur symbolique et de marché des eaux souterraines, ainsi qu'au coût de leur gestion. La principale contribution de cette approche tridimensionnelle est de mettre en évidence les facteurs qui déterminent la pertinence politique, facteurs cruciaux mais souvent ignorés par la littérature sur l'eau en général. Cette approche met l'accent sur l'importance du contexte et sur l'importance du social dans la formulation des problèmes attachés aux eaux souterraines.

Ceci dit, la compréhension des facteurs derrière les problèmes n'est pas non plus suffisante pour rendre compte de la nature des mécanismes utilisés pour la gestion des ressources. Cette thèse soutient que les mécanismes de gestion, qui peuvent être coordonnés ou unilatéraux, résultent de la confluence de facteurs systémiques et socio-institutionnels. Par

facteurs systémiques nous entendons les asymétries de pouvoir déterminées par la géographie et l'accès aux ressources, ainsi que par les trois dimensions classiques déterminant la puissance : « tanks et dollars », et la capacité de contrôler les règles légitimes d'interaction politique ou de déterminer les « paradigmes » de gouvernance des ressources. Les facteurs socio-institutionnels renvoient quant à eux aux interactions sociales et aux systèmes institutionnels établis. Notre approche ne préconise pas un choix arbitraire entre les variables, tel qu'il est proposé par la théorie des « régimes » de l'eau ou par la littérature sur la « gouvernance » de l'eau, qui se sont respectivement spécialisées sur les aspects systémiques et les aspects socio-institutionnels. Notre recherche considère par contre que l'écart apparent entre ces deux approches peut être comblé.

L'intégration théorique que nous proposons est basée sur l'analyse des connaissances et des idées, un aspect implicitement ou explicitement partagé par toutes les théories de la gestion de l'eau. Les facteurs idéationnels opèrent comme un fil d'Ariane dans l'articulation des contributions académiques et dans la comparaison des cas empiriques. L'étude de ces facteurs permet par ailleurs l'articulation analytique des problèmes de l'eau souterraine avec les politiques de gestion des eaux souterraines. La distinction entre les « problèmes » et les « solutions » proposée dorénavant ne doit pas être confondue avec une interprétation fonctionnaliste de la gestion des eaux souterraines. Notre argument ne consiste pas à dire que la gestion des eaux souterraines résulte de l'existence des problèmes, mais plutôt que la formulation des problèmes d'eau souterraine est un élément constitutif du processus politique menant à la mise en œuvre des mécanismes de gestion. Les problèmes d'eau souterraine ne conduisent pas nécessairement à l'émergence de mécanismes de gestion, mais ils jouent un rôle essentiel dans les processus politiques qui déterminent la mise en œuvre des mécanismes de gestion.

Cet travail de recherche a donc deux objectifs : Expliquer d'abord l'indifférence historique à l'égard des eaux souterraines transfrontalières dans les débats politiques internationaux et identifier ensuite les facteurs qui déterminent la nature des mécanismes de gestion utilisés pour les gouverner. En d'autres termes, ce travail identifie les facteurs qui déterminent l'entrée des problèmes liés aux eaux souterraines transfrontalières dans l'agenda politique, ainsi que les facteurs qui façonnent la mise en œuvre d'approches coordonnées ou unilatérales pour la gestion des ressources. Les théories classiques sur l'émergence de régimes environnementaux internationaux affirment en effet que les mécanismes de gestion des ressources en eau sont fonctionnels à la résolution des conflits actuels et potentiels et –en fonction des préférences analytiques– sont, soit l'expression des préférences des États plus puissants, soit le résultat de processus de négociation politique. L'émergence d'accords internationaux pour la gestion des ressources en eau est généralement présentée comme une réponse aux menaces associées aux ressources, en fonction du pouvoir et des préférences des parties prenantes. Les recherches sur la gestion de l'eau s'occupent de mettre en évidence les facteurs qui sont à l'origine des conflits et de la coopération sur les ressources, ainsi que l'impact des cadres institutionnels sur les processus de prise de décision. La littérature inclut donc des théories centrées sur l'Etat et le pouvoir, et des approches plus fines qui examinent les institutions et les interactions politiques qui façonnent la création, la mise en œuvre et l'efficacité des mécanismes de gestion de l'eau à différents niveaux de gouvernance. Ceci-dit, les recherches sur les régimes hydriques ne traitent que rarement sur les facteurs qui déterminent l'émergence et le contenu des institutions afférentes à la gestion de l'eau, et ne s'occupent que très rarement des eaux souterraines. À la lumière des débats actuels sur la relative absence de cadres réglementaires pour la gestion des ressources en eaux souterraines transfrontalières à l'échelle mondiale et du rôle des institutions et du pouvoir dans la gouvernance environnementale, cette recherche fait donc le point sur les facteurs cognitifs qui, bien souvent oubliés ou implicites dans la

littérature disponible, sont néanmoins la clé de l'émergence des mécanismes de gouvernance destinés à ces ressources.

Le texte de la thèse est structuré en deux grandes parties. La première partie porte sur les aspects conceptuels et théoriques, et la seconde sur l'analyse des cas empiriques. Le premier chapitre présente des concepts de base sur les eaux souterraines et les aquifères et explore le caractère particulier et spécifique des problèmes associés aux eaux souterraines. Il passe en revue les facteurs qui déterminent la quantité et la qualité des ressources en eaux souterraines disponibles dans un lieu donné et les conséquences de l'exploitation humaine sur les ressources. Il explore le rôle joué par l'hydrogéologie –la discipline scientifique consacrée à l'étude de ces ressources– dans la transformation de la dégradation des eaux souterraines en «problème politique ». Ce chapitre examine la transformation de connaissances sur les ressources en objets politiques, à partir d'une évaluation des services pourvus par les eaux souterraines. Le deuxième chapitre aborde les débats académiques sur les facteurs qui expliquent l'émergence de mécanismes de gestion de l'eau. Il considère l'hypothèse qui affirme que la pénurie d'eau déclenche des conflits ou des processus de coopération politique, et examine les éléments de base de la théorie de l'hydro-hégémonie, une théorie Etat-centrique de la gestion de l'eau. Le chapitre continue avec une révision de la littérature sur la gouvernance de l'eau, en examinant le rôle des cadres institutionnels et des acteurs non-étatiques dans la gestion de l'eau. Il passe aussi en revue les processus d'interaction sociale qui sont derrière la formulation de nouveaux programmes pour la gestion de l'eau. A partir de l'examen critique de la littérature spécialisée, le troisième chapitre propose enfin un cadre analytique général pour l'analyse des cas, qui combine constructivement les approches systémiques et socio-institutionnelles. La présentation de ce cadre d'analyse est suivie par l'étude de trois cas de gestion des eaux souterraines transfrontalières qui représentent trois approches alternatives à la gouvernance des ressources. L'analyse des cas met l'accent sur les

processus qui ont mené à la gestion de trois aquifères : l'Aquifère franco-suisse du Gènevois ; le Système Aquifère Guaraní partagé par l'Argentine, le Brésil, le Paraguay et l'Uruguay ; et les aquifères Hueco et Mesilla-Bolsón situés dans la région du Paso del Norte, dans la frontière entre les EUA et le Mexique. Ces trois cas ont été choisis car, en addition à la variété des modes de gestion qu'ils illustrent, ils partagent également le processus menant à la reconnaissance des problèmes des eaux souterraines, et les facteurs qui déterminent les décisions de gestion.

Dans le cas de l'aquifère du Gènevois, la ville de Genève a progressivement accru sa dépendance des ressources souterraines en eau au cours du XXe siècle. Le processus a été en grande partie motivé par le coût relativement bas de l'extraction des eaux de l'aquifère régional, par rapport à d'autres sources alternatives d'eau potable. Les ressources en eau souterraine sont devenues essentielles pour le développement de certaines parties du Canton mais, plus généralement, ces ressources étaient une source d'eau douce alternative accessible à un prix compétitif qui permettait d'assurer l'approvisionnement d'eau en cas de contamination des eaux de surface régionales. La compréhension de l'hydrogéologie régionale a progressé de pair avec le développement de l'infrastructure de l'eau dans la région et avec la formation des experts chargés de la prise de décision sur les modes de gestion des eaux. Les connaissances hydrogéologiques ont révélé que le pompage intensif de la nappe phréatique par les services régionaux de l'eau risquait d'épuiser l'aquifère. La meilleure compréhension des ressources et des progrès technologiques ont créé des conditions pour que la ville de Genève puisse recharger l'aquifère et restaurer la nappe phréatique à un coût raisonnable, et potentiellement, en fonction du volume de la recharge, nier l'accès aux ressources aux communautés françaises impliquées. Cette information a simplifié la négociation d'un accord de gestion conjointe entre les parties prenantes. Réciproquement, l'absence d'une alternative économiquement compétitive a encouragé les autorités françaises à coopérer et à participer à

la recharge de l'aquifère Génévois. L'approche de gestion coordonnée fut adoptée dans un accord formel contraignant, qui fonctionne efficacement encore aujourd'hui. Bien que la légitimité juridique de cet accord était relativement douteuse avant la subsidiarisation de l'autorité de gouvernance environnementale qui eut lieu durant les années quatre-vingt, le mécanisme a facilité la mise en œuvre des actions nécessaires pour atténuer de manière durable les problèmes les plus urgents liés à l'aquifère Génévois.

Dans la région transfrontalière du Paso del Norte, entre les Etats Unis et le Mexique, la dépendance des eaux souterraines est due essentiellement à l'extrême aridité régionale et à l'intense compétition autour de l'utilisation des eaux de surface. L'utilisation des ressources souterraines a permis pour sa part une forte croissance économique et démographique régionale, malgré la rareté des ressources hydriques. Les connaissances des eaux souterraines issues de collaborations scientifiques se sont accumulées tout au long du XXe siècle, à partir de dialogues entre les experts et les institutions universitaires des deux côtés de la frontière. En dépit de la disponibilité relativement précoce des modèles décrivant les conditions hydrogéologiques régionales, la coopération scientifique dans le domaine a été cependant entravée par la méfiance politique bilatérale. A l'origine de cette méfiance, des tensions politiques héritées de la Guerre Froide et à une concurrence accrue autour de l'utilisation des eaux partagées. L'exploitation intensive et l'action des gestionnaires locaux ont provoqué la détérioration quantitative et qualitative des eaux souterraines stockées dans les deux principaux aquifères régionaux, le Hueco et le Mesilla-Bolsón. Compte tenu des expériences locales de gestion de l'eau de surface, des lois des eaux préexistantes et de la complexité du cadre institutionnel, la prise d'initiatives de gestion conjointe était interprétée comme un risque élevé, surtout par les acteurs intéressés par le maintien du status quo en matière de modes d'exploitation des eaux souterraines. La nature commune des problèmes des eaux souterraines a été néanmoins à l'origine de dialogues informels au niveau local, orientés vers

l'échange d'informations de base jugées nécessaires pour la prise de décisions stratégiques par les services d'eau locaux. Les informations tirées de ces échanges n'ont pas malgré tout débouché sur des modes de gestion coordonnés. Ceci dit, les actions mises en œuvre ont permis d'atténuer les problèmes associés à l'usage des eaux souterraines des deux côtés de la frontière, et de diminuer les tensions politiques dérivées. Bien que les mesures de gestion se soient avérées relativement efficaces dans l'atténuation des problèmes d'eau souterraine, le Hueco et Mesilla-Bolsón sont exploités de façon unilatérale en fonction des préférences des utilisateurs et des cadres réglementaires du Mexique et des États-Unis.

Dans le cas du système aquifère Guaraní, la reconnaissance des ressources en eaux souterraines résulte de la réforme des institutions académiques régionales qui ont suivi le processus de décentralisation institutionnelle et la démocratisation des années quatre-vingt dans le cône sud de l'Amérique Latine. Le système aquifère Guaraní a été introduit dans l'agenda politique par l'interaction des hydrologues régionaux et des agents des États et des organismes internationaux. La théorisation et la vérification empirique des connexions hydrologiques entre les aquifères régionaux situés sous l'Argentine, le Brésil, le Paraguay et l'Uruguay sont à l'origine de la consolidation progressive de l'hydrogéologie dans les institutions régionales d'enseignement et à la création de nouveaux réseaux d'experts dans la région. L'ampleur et l'importance géostratégique du système aquifère ont permis de faire appel aux ressources économiques des organismes internationaux voués à la recherche sur les ressources naturelles partagées et ont encouragé les appels à l'action politique domestique. Malgré l'impact fragmenté et généralement limité des problèmes d'eau souterraine liés à l'existence de l'aquifère, les fonctionnaires des États nationaux se sont naturellement posé la question sur la nature stratégique des ressources. L'identification de problèmes spécifiques liés à l'utilisation des ressources résulte d'un processus à plusieurs niveaux de coopération politique, qui a conduit à l'élaboration d'une série de politiques unilatérales et de politiques

coordonnées au niveau international dans des sections différentes du système aquifère. Les mécanismes de gestion incluent un accord-cadre multilatéral précisant les principes généraux de la gestion coordonnée des ressources partagées, ainsi que des politiques de gestion au niveau local coordonnées et unilatérales.

Au-delà des différences, comme nous l'avons constaté dans les trois cas la reconnaissance des problèmes de l'eau souterraine a été rendue possible par l'interaction de certains modes d'exploitation des eaux souterraines, par la meilleure compréhension des facteurs à l'origine des conditions hydrogéologiques, ainsi que par la valeur sociale attribuée aux services fournis par les ressources. Aucun de ces facteurs, pris individuellement, n'explique pas l'entrée des problèmes des eaux souterraines dans l'agenda politique. La dépendance croissante des ressources a augmenté la valeur de leurs services éco-systémiques, mais seulement quand elle a été couplée avec une compréhension «suffisante» des facteurs à l'origine de la dégradation ou de l'épuisement des ressources. En même temps, la valeur des ressources en eau souterraine est déterminée dans les trois cas par la disponibilité d'informations hydrogéologiques et de techniques de modélisation qui permettent de réfléchir sur les causes de la dégradation des eaux souterraines et sur les capacités requises d'exploitation et de gestion des ressources. Les interactions de ces trois facteurs mettent en évidence la nature sociale des problèmes d'eaux souterraines; la détérioration qualitative et quantitative des ressources ne devenant l'objet de politiques que lorsque les changements environnementaux sont rattachés à des intérêts particuliers et que les acteurs considèrent que les problèmes sont potentiellement résolubles. Le sens des problèmes change au fil du temps avec des nouvelles interprétations de la portée de la détérioration des eaux souterraines et avec l'émergence de nouveaux intérêts attachés au sort des ressources.

Les processus de construction sociale qui mènent à la reconnaissance des problèmes des eaux souterraines sont trop souvent délaissés par la littérature consacrée à la gestion de l'eau.

Les problèmes sont trop souvent considérés comme existant de manière préalable à l'élaboration des politiques ou, par défaut, présentés comme purement instrumentaux aux préférences stratégiques des acteurs politiques. En ce sens, la contribution peut-être la plus importante de l'approche constructiviste employée pour l'analyse des cas pourrait être de mettre en avant cette phase constitutive du processus politique. La formulation des problèmes d'eau souterraine est concomitante avec la constitution des acteurs qui interviennent et résistent face à l'émergence de mécanismes de gestion des eaux souterraines transfrontalières. Cette approche analytique souligne le fait que la reconnaissance des problèmes des eaux souterraines est parallèle à la formulation des préférences vis-à-vis de la gestion de la ressource ou, en d'autres termes, que la reconnaissance des problèmes des eaux souterraines est inséparable de l'implication de nouveaux acteurs dans le processus politique et de l'entrée des ressources dans l'agenda politique. Il s'agit d'un processus dérivé non seulement de «faits objectifs», mais aussi des nouvelles significations de ces faits dans des contextes socio-historiques particuliers.

La revendication du rôle des idées et des aspects sociaux des problèmes ne doit pas être confondue avec une critique post-moderne des théories classiques de la gestion de l'eau. Bien au contraire, les approches théoriques conventionnelles sont enracinées sur des facteurs idéationnels et cognitifs, quoique trop souvent de façon implicite. Sur ce constat, le cadre d'analyse facilite l'exploration de leur pouvoir explicatif à propos de la gestion des eaux souterraines transfrontalières. Cette approche est basée sur l'absence de contradictions fondamentales, au-delà des différences méthodologiques et analytiques, entre les théories des «régimes» et les théories sur la «gouvernance». Appliquée aux cas, l'analyse démontre ainsi que, bien que la reconnaissance des ressources soit une première étape cruciale dans le développement d'actions pour l'atténuation de leur dégradation quantitative et qualitative, la

mise en œuvre des stratégies de gestion différentes se déploie en fonction de facteurs systémiques et socio-institutionnels.

La compréhension des aquifères transfrontaliers et la reconnaissance sociale des problèmes d'eau souterraine ne déterminent pas l'émergence d'un type particulier de mécanisme de gestion. Les méthodes de gestion sont façonnées en fonction tant de la nature des problèmes que des asymétries de pouvoir, ossifiées dans les cadres institutionnels et contraignant les dialogues entre acteurs politiques bilatéraux. Dans les trois cas, l'émergence d'initiatives pour la gestion des ressources en eaux souterraines transfrontalières a pourtant accompagné le processus de reconnaissance de la détérioration des eaux souterraines comme un problème : la reconnaissance des problèmes des eaux souterraines s'est simplement avérée empiriquement inséparable de la formulation de stratégies de gestion. Dans le cas du Génévois, les réponses politiques aux problèmes de l'aquifère reflètent les asymétries de pouvoir qui existaient entre les parties au niveau régional, ainsi que l'engagement des responsables locaux intéressés par la résolution rapide des problèmes de gestion des ressources partagées. Dans le cas des Guaraní, les informations sur l'hydrogéologie furent à la fois instrumentales à l'introduction des eaux souterraines dans l'agenda politique et à la délimitation des dispositions concrètes de gestion, mais elles ont aussi comme une ressource stratégique pour l'autonomisation des réseaux scientifiques locaux. Dans le cas, enfin, de El Paso del Norte, malgré la bonne compréhension des problèmes créés par des pratiques d'exploitation unilatérales, les différences géopolitiques et les préférences au niveau local ont systématiquement joué contre la gestion coordonnée des ressources.

Les trois cas mettent ainsi en évidence que l'émergence de connaissances scientifiques sur les ressources n'est pas seulement motivée par des raisons politiques, mais aussi que les acteurs politiques sont conscients des implications des nouvelles connaissances en ce qui concerne les décisions de gestion et les négociations internationales sur les ressources

partagées. L'influence de ces nouvelles connaissances est d'ailleurs différente si la contribution de la science et de si l'expertise sur les eaux souterraines transfrontalières est considérée comme «connaissance objective» ou elle est par contre considérée comme «information contestée» (Stone, 2002). Les connaissances sur les eaux souterraines se considèrent contestables quand elles sont produites dans des situations où elles questionnent des cadres institutionnels et réglementaires préétablis. Ces cadres institutionnels découlent d'interprétations particulières et de processus de négociation politique et, en tant que tels, fournissent des normes à propos de la légitimité des nouvelles connaissances et des cadrages alternatifs des problèmes environnementaux. L'héritage des institutions de gestion de l'eau façonne en fait non seulement les possibilités d'intervention politique, mais il configure également les formes d'interaction entre les acteurs impliqués dans la production de connaissances et la prise de décisions pour la gestion.

Cette recherche suggère qu'il n'y a pas d'approche unique qui permette de rendre compte des modalités de gestion des eaux souterraines. Il n'y a que des mécanismes de régulation adaptés au contexte et aux interprétations dominantes sur les défis et les menaces spécifiques posés par l'utilisation des ressources. Les mécanismes utilisés pour la gouvernance de ces ressources ne peuvent en fait jamais garantir la résolution définitive des problèmes des eaux souterraines transfrontalières. C'est ainsi tout simplement parce que les problèmes des eaux souterraines sont une cible mouvante, leur contenu change inévitablement avec l'apparition de nouvelles utilisations des ressources, de nouvelles connaissances, et avec le changement de la valeur attribuée aux services qu'ils fournissent. Toutefois, cette variabilité implique aussi que la durabilité des mécanismes de gestion des eaux souterraines transfrontalières dépend nécessairement de leur capacité d'adaptation face à des nouvelles informations, au changement dans les capacités techniques disponibles, et à l'émergence de nouvelles valeurs sociales. La gouvernance des eaux souterraines transfrontalières doit alors se comprendre

comme un processus récursif : le résultat d'échanges dynamiques et conflictuels à plusieurs niveaux, entre acteurs et institutions qui reflètent les accords préalables sur les sources de légitimité dans la prise de décisions et les intérêts dont l'État se fait porteur. Ce processus se fonde et s'alimente d'interprétations, intégrés dans les institutions et mobilisées stratégiquement par les acteurs politiques. Les normes et les principes de gouvernance des eaux souterraines ne résultent pas du simple débat de préférences, les débats internationaux sur les normes et modèles de gestion peuvent catalyser le développement de nouvelles initiatives nationales de gestion des eaux souterraines par le biais de liens matériels et symboliques.

Des recherches supplémentaires sur la gestion des ressources en eaux souterraines transfrontalières devront considérer plusieurs questions qui ont échappé à la portée de ce travail. Dans quelle mesure les facteurs qui influencent l'émergence de mécanismes de gestion des eaux souterraines sont-ils pertinents par rapport à d'autres ressources naturelles? Quelles sont les particularités de l'eau vis-à-vis d'autres ressources naturelles? La littérature consacrée à l'analyse de la gouvernance environnementale devra s'attaquer simultanément aux facteurs micro et macro, pour affiner l'efficacité des mécanismes de gestion, et la portée théorique des débats portant sur la gouvernance de l'eau. La connaissance et la compréhension des facteurs qui ont une influence sur la gestion de l'environnement doit se libérer de contraintes sectorielles et disciplinaires. Les acteurs impliqués dans la gouvernance des ressources ont besoin de moyens pour expliquer les préférences et les résultats des négociations politiques. Une autre question plus spécifique, et peut-être plus critique, est la suivante : quelles sont les conséquences associées aux différentes approches choisies pour la gouvernance des eaux souterraines transfrontalières? La gestion des ressources peut être coordonnée ou unilatérale, mais le choix d'une approche plutôt que d'autre a des impacts importants sur les relations entre les parties et sur les modes d'utilisation des ressources. Cette recherche suggère que des

approches différentes peuvent être tout aussi fonctionnelles pour la résolution des problèmes des eaux souterraines transfrontières, mais elle ne tient pas compte l'effet que ces approches peuvent avoir sur les institutions existantes et sur les relations entre les pays qui partagent les ressources.

Explaining the Emergence of Transboundary Groundwater Management

*The Cases of Guaraní Aquifer System, the Hueco and
Mesilla Bolsón Aquifers, and the Génévois Aquifer*

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To my parents, Alicia and Jorge, my sister Mariana, and Diane

Abstract

Despite the diversity of the contributions to the analysis of water resources and the myriad of water management experiences, transboundary groundwaters have only relatively recently entered the international political agenda. In line with research dedicated to understanding the challenges associated with the management of water resources and the creation of environmental regulatory frameworks, this dissertation examines the emergence of mechanisms for the management of transboundary groundwater resources. In doing so, it makes a seemingly straightforward inquiry. What are the factors that trigger the emergence and implementation of groundwater management mechanisms? Drawing from the review of the literature and the comparative analysis of three cases of transboundary groundwater management, this research finds that the recognition of groundwater problems is determined by the interplay of three factors: the uses of groundwater, the features of the hydrogeological resources, and the social valuation of the eco-system services provided by the resources. In addition, it suggests that groundwater problems are not sufficient to explain the nature of the mechanisms employed for the management of the resources. It argues that management mechanisms, which may be coordinated or unilateral, result from the configuration of both systemic and socio-institutional factors.

L'Emergence de la Gestion des Eaux Souterraines Transfrontalières: Les Cas de l'Aquifère du Génévois, des Aquifères Hueco et Mesilla Bolsón, et du Système Aquifère Guarani

Résumé

Malgré la diversité de contributions concernant l'analyse des ressources hydriques et la multiplicité d'expériences de gestion de ces ressources, les eaux souterraines n'ont été incorporées dans l'agenda politique des relations internationales que très récemment. En ligne avec les recherches dédiées à la compréhension des défis associés à la gestion des eaux et à l'émergence des mécanismes de régulation pour la gestion environnementale, ce travail examine la création de mécanismes pour la gestion conjointe des eaux souterraines transfrontalières. Pour ce faire, il essaye de répondre une question relativement simple : quels facteurs ont été déterminants pour l'émergence et la mise en œuvre de mécanismes de gestion conjointe des eaux souterraines ? A partir d'une révision de la littérature disponible et de l'étude comparée de trois cas, cette recherche a trouvé que dans la reconnaissance et la formulation des problèmes des eaux souterraines interagissent toujours trois types de facteur : les usages de l'eau souterraine, les caractéristiques hydrogéologiques des aquifères et la valeur sociale attribuée à la disponibilité éco-systémique des ressources. Cette recherche a trouvé d'ailleurs que la simple existence de problèmes associés à la disponibilité des ressources ne pousse pas automatiquement à la création des mécanismes de gestion. Ces derniers, qui peuvent être coordonnés ou unilatéraux, découlent de la confluence d'éléments systémiques et socio-institutionnels.

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Preface

This work stems from a long process that involved many more travels and interactions, and much more time than I originally expected. It began in 2005 when I was still in Argentina in the final stages of a B.A. in International Relations at the Universidad de San Andrés. One of the graduation requirements was writing a research paper on an original topic. I explored topics of international environmental governance before I decided to narrow my focus to issues of international water management. It came to my knowledge that Argentina, Brazil, Paraguay, and Uruguay shared a vast underground water reservoir, and that the countries were, at the time, developing joint management policies. I was intrigued by the idea of vast, yet relatively unknown shared reserves of freshwater, and moreover by the political challenges inherent to their management.

My exploratory inquiries into the issue formed the basis of a Masters thesis in comparative policy at the Institut d'Etudes Politiques de Paris (IEP), which I pursued between 2005 and 2007. In that context, I had the opportunity to dissect the process that led to the 'discovery' of the Guaraní Aquifer System and the formulation of policies for its management. I interviewed scientific experts, public officials, and stakeholders who were directly involved in both the assessment of the resources and the creation of political responses aimed at the protection and sustainable exploitation of the resources. This research highlighted the general novelty of transboundary groundwater governance issues and found that the increasing interest in these resources was not exclusive to the region. The emergence of management mechanisms for transboundary groundwaters was a burgeoning phenomenon at the global level. Yet, although the issue of international groundwater governance resonated naturally with the myriad of studies, debates, and conflicts associated with international surface waters, the ontological and theoretico-conceptual linkages between surface and

underground waters remained unclear. Too often, studies of groundwater management simply re-applied to groundwaters theories formulated to explain the regulation of surface waters; they largely brushed over the specific impact of groundwater problems on international environmental policy-making, as well as the consequences of different management approaches on the long term quantity and quality of the resources.

An offer to pursue the doctoral program at the IEP presented the opportunity to further explore these theoretical issues, as well as to consider the fate of the Guaraní Aquifer System in comparison to other transboundary aquifers. In order to select cases worthy of comparative analysis, I interviewed legal scholars and water management specialists at UNESCO's International Hydrological Programme (IHP). I contacted them because at the time the IHP was spearheading an initiative known as ISARM, short for Internationally Shared Aquifer Resource Management, which was conducting a global inventory of transboundary groundwaters for the development of international guidelines for their management. Thanks to their knowledge of both positive and negative cases of groundwater management, meaning those in which policy-makers managed to successfully implement joint management mechanisms and those in which they failed, ISARM's input was instrumental to the selection of relevant cases. My interviewees recommended that I examine the emergence of a Franco-Swiss Convention dealing with shared groundwaters.

They stressed that the agreement constituted the first of its kind – a formal mechanism exclusively dedicated to the management of a shared aquifer, the G n vois Aquifer – and that the experience had a significant influence on the drafting of articles for an International Convention on the Use of Transboundary Groundwaters by the United Nations International Law Commission (ILC). They also suggested that I review the empirical foundations of the Bellagio Draft Treaty, which was formulated by American legal scholars based on the

frustrated attempts to jointly regulate groundwaters at the United States-Mexico border and was also foundational to the international legislative initiative. They stressed that not only would these cases inform me of the diverse issues associated with the emergence of groundwater governance mechanisms, but that they would also provide a vantage point from which to understand the influence of particular cases of environmental governance on the international law-making process. Most significantly, the cases offered stark counterpoints to the Guaraní Aquifer System. At the time, the management of the Guaraní Aquifer System was solely based on the informal coordination of activities between local-level stakeholders; the management of the aquifer was neither the object of a formal joint management mechanism nor of significant conflict between the stakeholders. In contrast, the G n vois Aquifer was the object of a formal management mechanism, while the transboundary aquifers located along the U.S.-Mexico border were governed according to the unilateral preferences of the countries without evident forms of international coordination. Despite their differences, however, these cases both informed and shaped the international guidelines for the management of groundwater resources. As such, they were not just indicative of the challenges inherent to the international management of the resources; they also influenced the governance of groundwater resources elsewhere through the legal codification of the experiences, which added a new and interesting layer of analysis pertaining to the multi-level linkages of environmental governance.

The tentative case selection settled with my engagement in the Dual Ph.D. program with Northwestern University, which involved a two-year fellowship and residence in the United States. The opportunity allowed me to become better acquainted with the complexities and particularities of water law in the U.S. and in Mexico and to improve my English writing skills. Courses at Northwestern University helped me better navigate not only the debates between environmental regimes and governance, but also the unending maze of institutions

that constitute environmental politics in the U.S. and abroad. Moreover, these courses and the inestimable guidance of Pr. Paul Friesema and Pr. Pablo Boczkowski allowed me to bridge the cultural gap between the structured and conventionalized American academia and the laissez-faire French approach to graduate work. I had the chance to explore the social and philosophical dimensions of scientific research, which had first become apparent during my research on the Guaraní Aquifer System. Pr. Ken Alder, in the context of his seminar on the history of science, helped me better understand the emergence of groundwater policies in light of interactions among the actors and institutions in charge of the production of knowledge about hydrogeology and water resources. This preparatory work, which was accompanied by the constant reworking of the theoretical and analytical framework that would be employed for the analysis of cases of transboundary groundwater management, led to extensive field work.

Field work extended between 2009 and 2011 and was accompanied by the progressive conceptualization and reframing of the issues of groundwater governance. I spent two months in Geneva conducting interviews with legal experts charged with the re-drafting of the Convention for the Management of the G n vois Aquifer, the public officials responsible for the daily management of the resources, and legal scholars working on the regulation of international waters. They helped me retrace the history of the management of the shared aquifer and emphasized the dynamic nature of groundwater problems, which are determined not just by ‘facts’ but also by the changing interpretations of those with a stake in their exploitation. In Paris, I had the chance to meet anew with the experts at the IHP to discuss preliminary findings and rework my hypothesis. Back in North America, I traveled in search of explanations for the limited number of joint groundwater governance mechanisms between the U.S. and Mexico, despite the apparently looming depletion of the shared resources. I was hosted and directed by Ed Hamlyn, lecturer at the University of Texas at El Paso. A life-long

resident of El Paso del Norte and a water management specialist, Mr. Hamlyn dedicated time and effort to help me better understand the convoluted history of regional groundwater management, as well as reach the key players and informants who helped me address my specific questions about the relationship between regional hydrogeology and groundwater policy-making. He facilitated contacts with scientists at the forefront of research in the study of regional groundwater resources and their management throughout the borderlands. I interviewed regional hydrogeologists and examined their role in the governance of the resources, participated in official bi-national conferences and stakeholder meetings, and discussed my hypothesis with prominent political scientists dedicated to the issues of shared water management. My work at the borderlands was accompanied by stays in Mexico D.F. and Washington D.C., where I had the opportunity to address the management of the resources from the perspective of the federal governments and non-resident stakeholders, private water service providers and activists.

In light of the existing contributions to the analysis of environmental management and empirical data gathered during field work, it became apparent that there is need for a more flexible theory for the explanation of the emergence and implementation of divergent approaches to the management of transboundary groundwater resources: a theory of environmental governance that does not focus exclusively on either the systemic factors that shape the emergence of management mechanisms or the socio-institutional factors that determine the outcome of regional policy-making initiatives, but instead one that constructively considers both dimensions as equally constitutive. This approach concedes the possibility, advanced by systemic theories, that transboundary groundwaters may not play a unique role in international politics, as well as recognizes, in line with socio-institutional considerations, that the ultimate formulation and implementation of water management mechanisms is riddled with uncertainties. In essence, this research emphasizes the importance

of capturing the processes that lead to the recognition of groundwater problems and explain the emergence of particular approaches to groundwater management, and of accepting that these mechanisms may never fully settle. This dynamic interpretation of environmental governance is more amenable to understanding change, as well as the factors that make particular institutional configurations hold still. My hypothesis is that the emergence of groundwater management schemes is determined by the interpretation of ‘groundwater problems,’ as it echoes structural power asymmetries and particular socio-institutional interactions. I propose an analytical framework for groundwater management initiatives that takes into consideration the unique features of groundwater resources and contributes to a more general theory of the factors that shape international environmental governance.

This research would have been impossible without the substantial financial support of the Graduate School, the Roberta Buffett Center for Comparative and International Studies, and the French Inter-Disciplinary School at Northwestern University, the *Institut des Amériques* at the *Institut de Hautes Etudes pour l’Amérique Latine* (IHEAL), the Ecole Doctorale of the Institut d’Etudes Politiques de Paris, and TOTAL. I would like to thank Olivier Dabène, Hendrik Spruyt, Ed Hamlyn, Pablo Boczkowski, and Paul Friesema for their inestimable guidance, support, and help. Without them I would not have been able to finish this work. Also, I would like to mention my dear friends, Lucas Gomez, Pedro Arieira, Lorna Mellon, Brittany Murray, Marina Zaloznaya, Liz Onash, Matias Montilla, Marie-Esther Lacuisse, Pierre-Louis Mayaux, Jose Luis Martin, Genevieve Quirk, and many others...

I - Introduction

Are there reliable and sustainable solutions for the problems triggered by the exploitation of water resources? Scholars and decision-makers have pondered over this question for centuries. They have created a vast body of work that describes and explains the many roles played by water in our societies, the factors that shape different approaches to its management,¹ and the relative effectiveness of the mechanisms formulated for the resolution of the conflicts derived from their use. These contributions have exposed the multifaceted nature of water resources and the convoluted relationship of the social and the natural. This concern for the understanding of the resources has echoed the interest in the control of water for survival and for development. However, despite the sheer number and diversity of the contributions to the analysis of water resources and the myriad of water management experiences, it is only relatively recently that a particular *kind* of water has entered the international political agenda. This research deals with the “invisible waters” stored in the natural underground reservoirs known as aquifers.

Groundwaters constitute about 96 percent of the global reserves of non-frozen freshwaters and between twenty-five and forty percent of the total drinking water available for human consumption (Morris, Lawrence et al. 2003, Shiklomanov and Rodda 2003). Groundwaters are an essential component of the global water supply of cities, industry and agriculture, whose exploitation has produced massive economic and welfare gains. The use of groundwaters has pulled millions out of poverty and permitted settlement in otherwise inhospitable regions of the planet (Moench 2003, Stephan 2007, UNECE 2007). Yet, up until

¹ Management mechanisms refer to the norms dedicated to the resolution of the problems associated with transboundary groundwaters. They include formal and informal arrangements that specify, for example, the volumetric allocation of groundwater among users, well-drilling standards, auditing procedures, etc. These norms are formalized in international accords and coordinated policy agreements, but may also be enacted informally.

the later part of the twentieth century, these waters were deemed too “secretive”, “mysterious,” and “occult” for the emergence of regulatory initiatives (Eckstein 1995, Eckstein and Eckstein 2005). As recently as 2002, only 27 percent of all international agreements dealing with shared waters even mentioned groundwaters (Eckstein 1995, Matsumoto 2002, Jarvis, Giordano et al. 2005); the relative absence of management mechanisms dedicated to these resources has led to situations of “colossal anarchy” and to the progressive and significant deterioration of these resources across the globe (Krishna and Salman 1999).

Over the past sixty years, however, driven by the increasing acknowledgement of the threats posed by the deterioration of groundwater resources, academic and political interest in groundwaters has grown significantly. Groundwater management has progressively become a major issue in global environmental governance discussions. It is currently a prominent topic in international conferences about water governance and the object of management initiatives at the local, regional and international levels (Yamada 2004, UNESCO-IHP 2010). In line with research dedicated to understanding the challenges associated with the management of water resources and the emergence of environmental regulatory frameworks, this dissertation examines the emergence of mechanisms for the management of transboundary groundwater resources. In doing so, it makes a seemingly straightforward inquiry. What are the factors that trigger the emergence and implementation of groundwater management mechanisms?

Theories advanced to explain the relative paucity of transboundary groundwater management mechanisms suggest that it is either the result of an insufficient understanding of the resources, the absence of significant signs of deterioration in the resources, or the unwillingness or incapacity of political actors to deal with them. The literature generally holds that groundwater management is a rational-functional response to known problems and the

threats associated with the resources according to the will and possibilities of the powerful. In addition to presenting a relative consensus that ‘power matters,’ the literature also posits that scientific knowledge often operates as a power resource for political actors; it is an instrument through which they can coerce and persuade adversaries. New knowledge can operate as a weapon to challenge the legitimacy of established institutional frameworks, destabilize dominant political alliances, and reshape environmental governance. Indispensable to the emergence of rational environmental governance mechanisms, knowledge about groundwaters facilitates not just the increased exploitation of the resources, but also the understanding of the causes behind the deterioration and depletion of the resources—the identification of those responsible and of the measures necessary to ensure the effectiveness of actions aimed at the mitigation of environmental problems. This work deals with the elements that underlie the emergence of knowledge about the resources and the role of knowledge in the shaping of environmental policy problems, the design, and the implementation of environmental management mechanisms, as well as the impact of different governance schemes on the fate of the resources.

In the literature, the factors that best explain the reform and emergence of water management mechanisms are the object of a heated academic debate. In general, scholars agree that the existence of water problems, actual or potential, is fundamental in explaining management initiatives, yet also that the existence of problems does not warrant the implementation of management solutions. Given the critical role of water in human survival, water management has been studied from the perspective of most, if not all disciplines of social science, which has led to the proliferation of interpretations of both its meaning and of the variables that are supposedly relevant to its analysis. Nevertheless, despite the number and variety of contributions to the study of water, the vast majority of research has focused on the management of surface waters: river basins, lakes, and seas. In comparison to the sizeable

theoretical corpus on surface water management, the emergence of mechanisms for the management of groundwater remains significantly under-theorized. Is this simply because the existing theories of the water management literature are applicable to groundwater and aquifers? Or are we in need of new theories reflective of the ontological particularities of groundwater?

This research advances the thesis that the recognition of groundwater problems is determined by three factors: the uses of groundwater, the features of the hydrogeological resources, and the social valuation of the eco-system services provided by the resources. The first factor refers to the level of exploitation of the resources, which is determined by the social demand for and uses of groundwaters as well as the relative availability of technology to draw the resources from aquifers. The second factor is the specific hydrogeology of the region in which groundwater exploitation takes place, which refers to the features of the aquifer –i.e. storage capability, recharge and discharge volumes, natural groundwater quality– and its vulnerability to anthropogenic and non-anthropogenic disruptions. The third factor is the social valuation of the eco-systemic services provided by the groundwaters; it alludes to the symbolic and market value of groundwaters, as well as the cost of their management. The main contribution of this layered approach is to highlight the factors that shape political relevance, crucial aspects often ignored by the mainstream water literature. It exposes the contextualized and constructed meaning of groundwater problems.

Groundwater problems are, however, not sufficient to explain the nature of the mechanisms employed for the management of the resources. This work contends that management mechanisms, which may be coordinated or unilateral,² result from the

² Coordinated management mechanisms are enforced through formal and/or informal arrangements that establish norms for the legitimate governance of the shared resources, while the unilateral management of the resources is conducted without such coordination mechanisms.

configuration of both systemic and socio-institutional factors. Systemic factors are the power-asymmetries determined by geography and relative access to power resources –such as ‘tanks and dollars,’ the ability to control the rules of legitimate political interaction, or determine the ‘paradigms’ of groundwater governance– and socio-institutional factors refer to the social interactions mediated by established institutional systems. This approach does not advocate cherry-picking from the ‘water regimes’ or the ‘water governance’ literature, each of which narrowly specializes in systemic or in socio-institutional aspects. Instead, this research argues that the gap existing between these two analytical strands can be bridged.

This integrated approach is rooted in the analysis of knowledge and ideas, which are issues implicitly or explicitly central to most if not all theories of water management. Ideational factors are used as an Ariadne’s thread for the articulation of the seemingly disparate academic contributions, as well as for the comparison of empirical cases. Moreover, the study of these factors serves the analytical articulation of groundwater problems with groundwater management policies. In fact, the distinction of ‘problems’ and ‘solutions’ suggested above should not be confused with a functionalist interpretation of groundwater management. The argument is not that groundwater management results from the existence of problems, but rather that the formulation of groundwater problems is a constitutive element of the political process that leads to the implementation of different management mechanisms and one that requires further attention. Groundwater problems do not necessarily lead to the emergence of management mechanisms, but they are pivotal in the political processes that determine whether new management mechanisms are established.

Overall, the work is structured in two major sections, the first dealing with conceptual and theoretical factors, and the second with empirical cases. The first chapter introduces fundamental concepts about groundwaters and aquifers and explores the unique features of

groundwater problems. It reviews the factors that determine the quantity and quality of groundwater resources available in a given location and the effects of human exploitation on the resources. It explores the role played by hydrogeology, the scientific discipline dedicated to the study of groundwaters and aquifers, in the translation of knowledge about groundwater deterioration into “policy-problems.” The chapter examines the socio-historically specific translation of knowledge about the resources into problems, as determined by the valuation of groundwater services. The second chapter addresses the academic debates about the factors that best explain the emergence of water management mechanisms. It introduces the seminal debate over whether water scarcity triggers political conflict or cooperation, and examines the basic components of the hydro-hegemony framework, a prototypical power-based state-centric theory of water management. The chapter follows with a review of the water governance literature, which looks at the means through which institutional frameworks and non-state actors shape water management. It reviews the socio-institutional factors that underlie processes of social interaction and the formulation of new water management schemes. Then, based on the critical review of the specialized literature, the third chapter outlines a general framework for the analysis of cases of transboundary groundwater management that constructively combines elements from systemic and socio-institutional approaches. The presentation of the analytical framework is followed by the presentation of three cases of transboundary groundwater management, representing three alternative approaches to the governance of the resources. In order, the cases involve the management of the Franco-Swiss G n vois Aquifer, the Argentinean, Brazilian, Paraguayan and Uruguayan Guaran  Aquifer System, and the Hueco and Mesilla Bols n aquifers located in the Paso del Norte region at the the U.S.-Mexican border. These case studies demonstrate that the development of joint governance mechanisms always depends on the availability of mutually recognized assessments of transboundary resources supporting a common framing of the

problems. Moreover, these interpretations reflect not only hydrogeologic conditions, institutional frameworks and geopolitics, but also the idea that the implementation of governance mechanisms is driven by and responds to multi-level political interactions.

II - The Dynamic Nature of Groundwater Problems

Before addressing the specific factors behind the emergence of the mechanisms used to manage groundwaters, this section introduces fundamental concepts about groundwaters and aquifers and explores the unique features of groundwater problems. It reviews the factors that determine the quantity and quality of groundwater resources available in a given location, as well as those that lead to the recognition of groundwater deterioration as a “problem.”

A - Introduction: Fundamental Concepts about Groundwater and Aquifers

Groundwater is not fundamentally different from the water in rain, rivers, and lakes. Different mediums determine the behavior and chemical features of water; they make different “kinds of water.” The medium of groundwater is the aquifer: permeable or fractured deposits saturated with water molecules.³ In fact, due to the lack of distinct physical properties distinguishing aquifers from other geologic formations, aquifers tend to be defined with relative ambiguity in the hydrological sciences literature (Freeze and Cherry 1979, Seaber 1988, Matsumoto 2002). As noted by Marsily (1985), an aquifer is an analytical abstraction that is by no means equivalent to any single geologic, lithologic or stratigraphic unit. Geologic formations simply “become” aquifers when they are saturated with water. By virtue of their definition, groundwaters and aquifers are ontologically inextricable from each other. Deposits with water-bearing capacity simply become aquifers as water seeps into them, and waters become groundwaters as they enter aquifers. The occurrence and behavior of groundwaters are never independent from the features of the terrain. Natural geologic and hydrologic factors simultaneously shape the quantity and quality of groundwaters and

³ Groundwaters are seldom stored in giant underground caves or underground seas. Rather, they are stored below the surface of the ground in the naturally occurring microscopic openings and fractures of the terrain.

determine the relative vulnerability of the aquifers to different exploitation patterns. Groundwaters are of “dual character:” a moving mineral resource whose features depend on the natural conditions of the territory, but also sensitive to the effects of human intervention (Zekster and Everett 2004).

Aquifers recharge when waters seep into them and discharge when waters exit the system. Recharge reflects the seepage of surface waters and the reception of waters out-flowing from connected hydraulic systems, while aquifers discharge when groundwaters exit the system through evotranspiration (evaporation) or passage to other systems. The balance between the water that enters the system and that which flows out of or is consumed from the aquifer is known as the hydrologic budget of the aquifer. In general, this budget is sensitive to climatic conditions, as well as to changes in the hydraulic systems that are connected to the aquifer. In humid climates, the volumes of water naturally recharging the aquifer will tend to be larger than in arid or semi-arid regions, where surface waters and rainfall are scarcer. The availability of surface waters tend to contribute to the aquifer’s recharge. Nonetheless, major aquifers may exist in extremely arid areas. In those cases, groundwater reserves are often composed of “fossil waters” stored before the aquifer lost its natural sources of recharge or during ‘wetter’ climatic conditions.

The movement of groundwaters depends on the structural hydrodynamic features of the aquifer. The speed of the groundwater flow within the aquifer is then determined by the permeability and thickness of the deposits and by the hydraulic head. Groundwater may flow quickly through karsts (soluble carbonated soils), slowly through sandy soils, or remain immobile in permafrost and low permeability bedrocks. In most cases, groundwaters are neither stagnant nor in rapid circulation, but instead flow slowly through the terrain. In this sense, one of the most critical features governing the movement of water within an aquifer is

determined by whether the aquifer is confined or unconfined. Unconfined aquifers are those in which groundwaters only partially saturate the water-bearing geologic formation. Often located close to the surface, the depth at which groundwater is found in these aquifers is known as the water table, and the groundwaters move following the gradient of the terrain driven by gravity. Conversely, in confined aquifers, groundwater is sandwiched between layers of impermeable deposits, which significantly limits the vertical flow of water and creates particular internal piezometric⁴ conditions within the aquifer. The confining beds pressurize groundwaters and prevent them from flowing to the topography of the terrain. Instead, they move according to the aquifer's internal pressure gradients, and flow goes from high pressure to low.⁵

Groundwater's natural geochemistry reflects the composition of the host-rock or soil in which it circulates, according to its solubility and the rate at which water circulates in it, and the quality of the resource depends on the aquifer's geochemistry and morphology. Sedimentary rocks and soils naturally carry different concentrations of mineral components such as magnesium, calcium, chlorides, arsenic, boron, and selenium. The type and concentration of these elements in the aquifer can affect the quality of groundwater, and "*the chemical composition of groundwater can change measurably over distance along the flow path as in situ processes interact*" (Jousma and Roelofsen 2004). Furthermore, natural linkages to other hydraulic systems affect the quality of the waters if they supply the system with waters of lesser quality. It is not uncommon, for example, to find aquifers with naturally high concentrations of saline waters resulting from either the high concentration of chlorides in the terrain or the intrusion of saline waters into the system. Occasionally, high

⁴ Piezometric conditions refer to the atmospheric pressure conditions within the aquifer.

⁵ Wells drawing groundwater from confined aquifers are known as artesian wells and may naturally flow due to the difference between the surface atmospheric pressure from that of the aquifer.

concentrations of hazardous minerals limit the usability of the resources, most renewable groundwater supplies tend to be of adequate quality for human uses (Krishna and Salman 1999, Postel 1999).

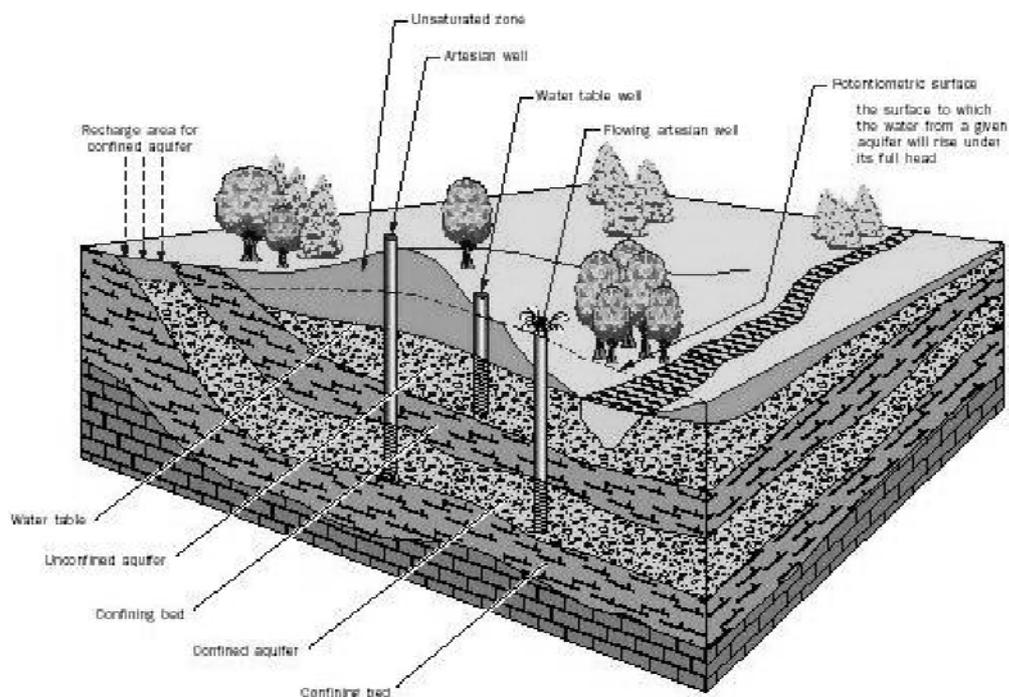


Figure 1: Aquifers and Groundwater

Source: Adapted from Water Encyclopedia Online <http://www.waterencyclopedia.com/Ge-Hy/Groundwater.html#b> (Retrieved January 2009).

Llamas and Custodio (2003) illustrate the dynamic nature of groundwater problems by noting that the drying up of wetlands was once considered a positive externality of the intensive exploitation of groundwater. Indeed, it allowed the exploitation of lands otherwise unavailable for agriculture. Today, however, wetlands are widely acknowledged to be important components of the natural environment and thus deemed worthy of protective measures. Sophocleus (1993) provides another example in his review of the evolution of the concept of “sustainable yield.”⁶ Originally, the notion was borrowed from surface water

⁶ The evolution of the notion of sustainable yield also highlights the challenges that groundwaters pose when attempting to use “borrowed” approximations to manage them. The inclusion of new dimensions to groundwater management debates was not limited to the inclusion of new criteria in the

reservoirs' managers. Water reservoirs are used to balance yearly water supplies: they store waters during humid months and discharge them during dry periods. In their design, the relationship between "capacity" and "yield" is crucial. "Yield" is the amount of water that can be supplied from the reservoir, while "capacity" is the volume of water that can be stored in the reservoir. Sustainable yield (also known as safe or perennial yield) is the maximum quantity of water that can be withdrawn from the reservoir during the critical dry period without compromising the supply during this period. When applied to groundwaters, the notion initially signaled the theoretical *quantity* of water that could be extracted from an aquifer without hindering the total volume of water stored. It essentially equaled the volume of recharge of the aquifer. In time, however, the notion began to encompass other issues as well. The problems associated with the yield of an aquifer changed to reflect new social concerns, evolving from addressing quantitative issues alone to including quality issues and legal issues. Ultimately, the sustainable yield of an aquifer would be defined more loosely as *"the amount of water which can be withdrawn from (a ground-water basin) annually without producing an undesired result"* (Todd 1959). In this example, the deterioration of groundwater resources and changing social interpretations altered the defining features of groundwater problems.

Groundwater problems are never static; they are shaped and reshaped by changes in the exploitation of the resources, the understanding of hydrogeological features, and the social valuation of the services provided by the resources. The exploitation of the resources refers to the role of groundwaters as input in productive processes and culture. It depends on the availability of technologies granting access to the resources, and determines the anthropogenic-driven changes in natural hydrogeologic conditions. The understanding of

determination of the "sustainable yield" of aquifers; rather, it reflected both the progressively better understanding of their particularities and the way in which they were associated with issues in political agendas.

hydrogeology denotes the availability of knowledge about the causal connections existing between changing hydrogeologic conditions and exploitation patterns. It is most often indicated by the availability of mathematical models synthesizing the geological, mineralogical and hydraulic particularities of a given aquifer.⁷ Models facilitate fact-based theorization about the causes of groundwater deterioration and are indispensable for the emergence of rational policies for the management of groundwater resources. Finally, the social valuation of groundwater services refers to the interpretation of the effects of hydrogeologic deterioration. The stakes attached to the fate of groundwater resources are determined by their cultural and market value. The social value of groundwater services reflects the costs attached to hydrogeologic deterioration and determines the importance and urgency of mitigating hydrogeological deterioration. In essence, the existence of groundwater problems cannot be directly correlated with the depletion or deterioration of groundwater resources. The quantitative and qualitative deterioration of groundwater resources “becomes” problematic as it affects specific social practices—when it is interpreted as such. This is because groundwater problems reflect not just the deterioration of aquifers and their waters,

⁷ Hydrogeologic models are a framework for the systematic organization of large amounts of information about the hydrology and geology of a given geographic area. The basic unit of a model is a lithofacie, which is the determined set of geophysical, geochemical, and hydrologic properties of a given deposit. Lithofacies are the primary components of hydro-stratigraphic units, which are composed of the assemblage of multiple superposed lithofacies. A given aquifer may be composed of multiple hydraulically-connected hydro-stratigraphic units. Aquifer models help determine: 1. the rate of renewal or volume of recharge, which is the volume of water entering the system in a given period of time; 2. the volume of discharge, which is the volume of water exiting the system; and 3. the volume in storage, which is the volume of groundwater stored in the aquifer (Zekster and Everett 2004). As noted by Konikow and Bredehoeft (1992, taken from Hawley 2000, 7), groundwater models can never be fully validated. By definition, hydrogeologic models may always be refined as new information emerges and as technological improvements refine the temporal and geographic scale at which model-based predictions remain valid. In fact, many models are constructed on the basis of hypotheses, which are later confirmed or refuted on the basis of empirical investigations. The creation of successive models is always expected. The most prominent computer modeling software for groundwater, MODFLOW, was only developed in the 1970s.

but also social processes: factors that explain the significant transformation of ‘groundwater problems’ over time.



Figure 2: Groundwater problems

B - The Effects of Exploitation on Quality and Quantity

Aquifers are normally vulnerable to human intervention: the artificial extraction of groundwater from an aquifer can affect the quantity and quality of groundwater, as well as the physical structure of the aquifer (Llamas and Custodio 2003). The vulnerability of aquifers to these problems depends simultaneously on hydrogeologic particularities and the nature of human intervention.⁸ In unconfined aquifers, for example, groundwater extraction leads to drops in the water table, which means that waters are found at progressively greater depth; in

⁸ These issues affect not only we humans as they can also impact the multiple ecosystems that are hydraulically dependent on the aquifers.

confined aquifers, the same phenomenon leads to the progressive reduction of the surface pressure, which is the water pressure within the aquifer. Lowered water tables or reduced surface pressures indicate that groundwaters are being extracted at rates that exceed the aquifer's recharge. In most cases the quantitative deterioration of an aquifer is reversible. If extraction is reduced or stopped, new waters will often recharge and restore the aquifer. Depletion may not be naturally reversible if the aquifer lacks sources of recharge. The extraction of water from aquifers that lack recharge is known as the "mining of aquifers" (Cressey 1957). Unfortunately, this is often the case for aquifers located in arid and semi-arid areas of the world, which is where they are most intensively exploited and are most necessary to socio-economic development. The intensive exploitation of an aquifer may also affect the quality of the groundwaters. Artificial groundwater pumping creates zones of lesser surface pressure, which draw groundwaters towards them. As originally established by Darcy in 1856 during his study of groundwater in the French city of Dijon, the size and shape of these "cones of depression" is determined both by the intensity of pumping and the hydraulic coefficient of the soil. Heavy pumping modifies the direction of groundwater flow and may impact the quality of groundwaters, either by drawing waters of lesser quality from adjacent systems (induced recharge, lateral encroachment) or from other sections of the aquifer. Moreover, the proliferation of wells and pumps multiplies the vectors through which pollutants can enter the aquifer. Last but not least, the extraction of groundwater may also modify the physical structure of aquifers. For example, the physical structure of the aquifer may collapse as water is extracted, diminishing its ability to stock water. This is known as land subsidence.⁹ Indeed, the extraction of groundwaters always has an impact, whether on

⁹ Land subsidence is often associated with increases in the frequency of flooding, because collapsed aquifers are unable to capture runoff.

the hydrogeological features of the aquifer, the chemical properties of the water, or the ecosystems connected to the aquifer.¹⁰

Archaeological expeditions have found wells and structures that were built for the exploitation of groundwaters more than eight thousand years ago (Jarvis 2006, Narasimhan 2009). Groundwater has long been tapped from springs, extracted through the diversion of river-base flows, and pulled from wells and horizontal galleries (Llamas and Custodio 2003). Nonetheless, the extensive and intensive use of groundwaters is a relatively recent phenomenon. Described as a “silent revolution,” global groundwater exploitation and concomitant threats to the quality and quantity of the resource have intensified significantly in the past few decades. The revolution has been driven by the use of new pumps and well-drilling techniques, which have reduced the costs and complexity of extracting groundwaters from aquifers, but have also led to the intensive exploitation and significant deterioration of the resources (Custodio and Llamas 1983, Llamas and Martinez-Santos 2005). Human activities, whether agricultural, industrial or residential, may act as sources of ground water contamination. Agricultural sources include chemical fertilizers and animal waste, which contaminate aquifers when they are stored near conduits to groundwater (wells and sink holes) or accumulate in surface depressions. Industrial contamination happens with the spillage, leakage, or improper handling of industrial waste into an aquifer. It may also occur with the improper disposal of wastewater into septic tanks, the usage of dry holes and cesspools to store waste, and the storage of hazardous materials in areas lacking drains or catchment basins. In a similar way, residential wastewater systems can contaminate groundwater with bacteria, viruses, nitrates derived from human waste, and organic compounds. In particular, injection wells used for domestic wastewater disposal (septic

¹⁰ For a general synthetic review, see (Ganoulis, Aureli et al. 2011)

systems, cesspools, drainage wells for storm water runoff, groundwater recharge wells) commonly affect groundwater quality if located close to drinking water wells. These contaminants include household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline, and diesel fuel. Ultimately, however, the environmental impact of the use of the resources is determined by geographically specific factors: analogous exploitation patterns may have a different impact on the resources depending on the location in which they take place. The consequences of groundwater exploitation are often uncertain; they depend on the idiosyncratic hydrogeological features that determine how a given aquifer will respond to pumping (Llamas and Custodio 2003).

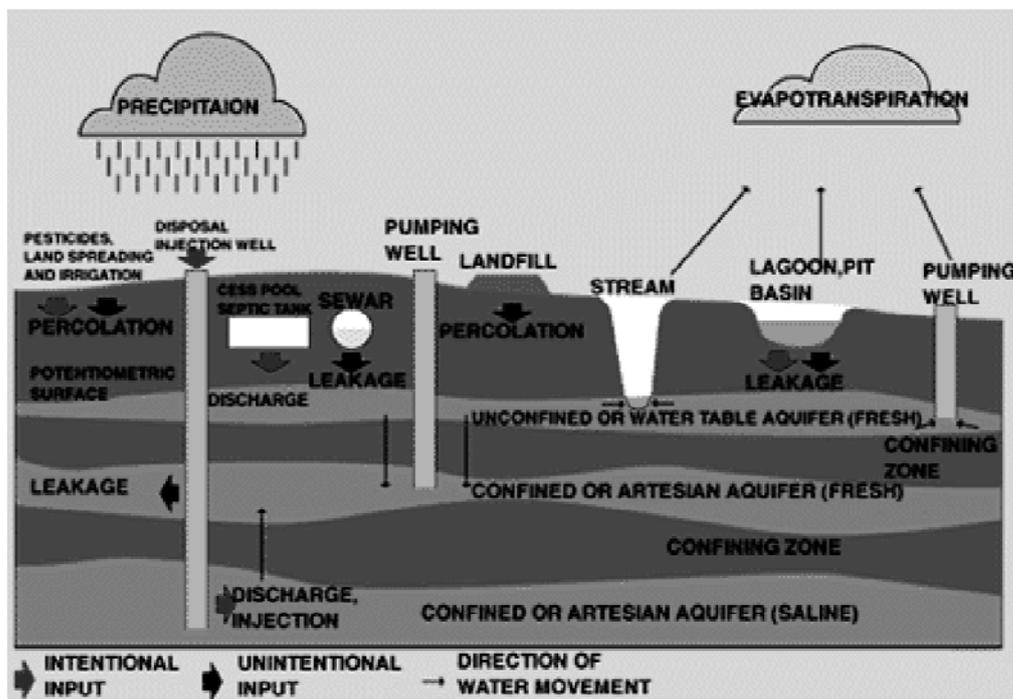


Figure 3: Basics Concepts and Terms about Groundwater

Source: Adapted from Environmental Protection Agency, Office of Water Supply and Solid Waste Management Programs, 1997. Waste Disposal Practices and Their Effects on Groundwater. U.S. Government Printing Office, Washington, DC.

C - Hydrogeology for the Assessment of Groundwater Deterioration

The assessment of the impact that humans have on groundwater resources is possible through the practice of Hydrogeology, which is the scientific discipline dedicated to the study and understanding of groundwaters and aquifers. Hydrogeological assessments specify the factors behind the deterioration of the resources and facilitate the formulation of policies to deal with groundwater problems. The scientific discipline of hydrology plays a crucial role determining the nature of groundwater problems. Hydrogeological analyses help determine, for example, whether the deteriorating quality of groundwater is the consequence of pollution from anthropogenic sources or a natural occurrence of the geochemical composition of the terrain. The hydrogeological characterization of an aquifer specifies, among other things, its capacity to store groundwater and the rate at which its reserves are replenished or exhausted.

The technology, techniques and expertise necessary for the proper assessment of aquifers have developed relatively recently and have echoed theoretical refinements in the sciences dedicated to the study of aquifers and groundwater. In fact, although theories about the occurrence and flow of groundwaters have been traced back to thinkers in ancient Greece, the actual discovery of the critical, basic laws that govern groundwaters only occurred in the mid-nineteenth century, and most tools and methods that allow for more precise characterization of hydrogeological features date from the second half of the twentieth century. The literature dedicated to the history of hydrogeological knowledge highlights the successive technological and theoretical breakthroughs that facilitated the understanding of these otherwise invisible resources (Narasimhan 2009) (Fetter Jr and Deming 2004, Narasimhan 2005). The history of the knowledge about groundwater resources may be separated into two clearly distinct eras: a pre-scientific period marked by pragmatism and speculation from the first millennium B.C. to the end of the Middle Ages, which was followed by a second period characterized by quantification, systematic experimentation and

knowledge accumulation by means of the scientific method. The later phase was supported by the contributions of Hydrology and Geology. These “parent” disciplines provided the basic conceptual tools and methodologies for the disciplinary emancipation of Hydrogeology. In the field of hydrology, the passage into the second period was triggered by the work of French scientists Pierre Perrault and Edmé Marriotte (Biswas 1970). These scientists published data and calculations in the 1670s and 1680s that demonstrated that precipitation was the precursor of surface stream flows. Years later, the English scientist Edmund Halley estimated the quantity of water involved in the hydrologic cycle of the Mediterranean Sea and surrounding lands (Biswas 1970). Perrault, Marriotte, and Halley conceptualized the stepping-stone of water science: the hydrologic cycle. Their quantitative analysis of experimental data proved that the water flowing in the earth's surface arrived there as rain, and that the earth's water moves in a closed loop between earth, ocean, and atmosphere. These discoveries, along with the establishment and recognition of the scientific method as a legitimate epistemological methodology, led to the establishment of hydrology as an independent field of scientific inquiry.¹¹ In a similar fashion, the original contributions of James Hutton in the 1780s provided a fundamental theory of the earth system that, popularized later by Lyell (1858), became the basic conceptual framework for the systematic study of geological formations, soils, and the establishment of geology as a specific area of scientific inquiry.

The pursuit of hydrogeological knowledge was originally associated with pragmatic calls to rationalize the well-drilling strategies necessary to supply cities and develop infrastructure for irrigation, as well as to supplant inaccurate and unreliable methods used to

¹¹ The term Hydrology is attributed to the work of English physicist and chemist John Dalton, which took place about 1750. The final acceptance of hydrology's scientific status came through institutional recognition in the first half of the twentieth century with the creation of the Section of Scientific Hydrology in the International Union of Geodesy and Geophysics in 1922, and the creation of the Hydrology Section of the American Geophysical Union in 1930 (Biswas 1970)

find groundwaters: “dowsing”, “witching” and divining rods (Barraque 2008). Hydrogeology was indeed fostered as an instrument for progress and functional to the resolution of practical controversies.¹² It was originally defined as “the coordinated scientific data regarding the occurrence, motions, and activities of subsurface water, and the hydrologic properties of water-bearing materials” (Tolman, p.vii.), or in more general terms, as the articulation of geologic and engineering data for the evaluation of the hydrologic conditions of rocks and for the estimation of the capacity of underground reservoirs and rates of movement in underground flows. The legitimacy of the scientific discipline was rooted in the inability of other disciplines to address groundwaters, the increasing exploitation of the resource, and the need of rational guidelines for litigation in regard to ownership of groundwater.

Henry Darcy and Jules Dupuit, in 1856 and 1860 respectively, first theorized about the basin-wide motions of groundwater in layered sedimentary systems and established that these waters move according to pressure gradients and the porosity of the soil. They estimated groundwater infiltration and flow based on a quantitative theory. This seminal work completed the hydrologic-cycle puzzle and established the bases for the modern study of groundwaters. Initially, however, the findings and information on hydrogeology were

¹² In the U.S., it was Oscar E. Meinzer (1923) who arguably first had the vision and the philosophical bent to position groundwater hydrology as a separate discipline within the earth sciences. His efforts were joined by those of others, such as Cyrus F. Tolman, who initiated programs devoted to “groundwater” at the University of Arizona and then at Stanford University between 1905 and 1940. Tolman’s course was unique at the time, and its syllabus evolved into a comprehensive treatise that eventually became the standard for courses of Hydrogeology until the 1950s (Remson 2002, Fetter Jr and Deming 2004). The textbook authored by Tolman, Ground Water (1937), was the first general treatise of Hydrogeology. It summarized the results of the intensive study of subsurface water in the United States combining both scholarly research and engineering applications. It emphasized the need for geologic investigation and engineering analysis to solve hydrogeological problems. Ground Water reviewed the general principles that govern groundwater behavior in order to “assist the attorney in preparing for litigation involving subsurface water, and [...] to assist in the development of sound ground-water law founded on present-day scientific knowledge.”(p. 16) Hydrogeology was proposed as a tool to set “people free [...] from superstitions regarding the mysterious and “unlawful” wandering of water underground” (p. 23).

published in journals of geology and hydrology, and courses on aquifers and groundwater were included only as partial requirements in the curricula of other scientific disciplines. Eventually, as the theoretical corpus dedicated to the particulars of hydrogeology expanded, the field gained legitimacy as a scientific discipline distinct from the other earth sciences. Supported by the utility of its findings, the discipline slowly carved out its own space in academic institutions. The accumulation of knowledge in the field occurred simultaneously with the development of new techniques and technology, which allowed the assessment of hydrogeologic conditions. These included the refinement of well-drilling operations, the better survey of geologic formations, and the installation of more extensive groundwater monitoring networks.¹³

In general, the discovery of hydrogeological “truths” and the recognition that the ways in which groundwaters are utilized vary from location to location and over time helped “make sense” of groundwater resources and distinguished natural from anthropogenic sources of environmental deterioration. Yet, in spite of these advances, knowledge about specific groundwater resources resulted from the localized practice of hydrogeologic inquiry. The natural laws that govern hydrogeology translate into knowledge about resources only as empirical hydrogeologic data is translated into models that explain the hydrogeologic features and changes. The availability of knowledge about hydrogeology depends on scientific and technical expertise, as well as on the availability of the economic and institutional resources

¹³ The first documented monitoring system dedicated to the follow-up of groundwater levels was installed in the United Kingdom in 1845. France started monitoring groundwater quality in 1902. The systematic monitoring of European groundwaters began in the 1950s, but qualitative monitoring became widespread only toward the 1980s (Jousma and Roelofsen 2004). In the United States, the monitoring of groundwater began in the early twentieth century: observations wells were built in New Jersey in 1923 and Pennsylvania in 1925, and nationwide monitoring networks were established in the 1960s. In developing countries, groundwater monitoring was less systematic, usually associated with one-shot international projects and the analysis of the resources used for the supply of larger urban centers (Akiwumi 1994).

necessary for data collecting. Consequently, and since the conditions of possibility of the practice of hydrogeology tend to vary significantly across locations, hydrogeologic resources are well understood in some places, while remaining poorly understood in others. The absence of geographically specific hydrogeologic knowledge precludes the ‘problematization’ of changing hydrogeologic conditions. In other words, the localized practice of hydrogeology is inextricable from the recognition of groundwater problems. Reciprocally, the improvement of the technological tools used for the assessment and exploitation of the resources may lead not just to the identification of the natural principles that govern groundwaters and easier access to the resources, but also to the objectification of the resources in terms apprehensible by politics.

D - Groundwater Services and their valuation

Although the significant deterioration of the resources, driven by the increasing recognition of and reliance on groundwater resources, is undeniably a significant component of groundwater problems, it is not sufficient to account for their emergence. Ultimately, groundwater problems result also from the social tensions associated with changes in the quantity and quality of groundwater resources. These are created by the value attached to groundwater resources, which depends on the role of the resources in economic and cultural processes.

In this sense, ecological economists suggest the conceptualization of environmental problems as the result of the tensions produced by the deterioration of environmental services (Daily 1997, Mooney and Ehrlich 1997, Boyd and Banzhaf 2007, Fisher, Turner et al. 2009). These services refer to the particular benefits that natural resources provide to humans and denote the uses that humans make of nature and the benefits they derive from these uses. In the case of groundwater, environmental services include the use of groundwaters for

consumption, for irrigation, and for industrial processes, as well as the waters' role in cultural practices. This approach considers both the tangible and intangible benefits derived from the uses of groundwater.¹⁴ The assessment of the value of the multiple services provided by groundwaters is often empirically challenging; it reflects the often-complicated relationships that nature has with the social.¹⁵ Accordingly, it is too often reduced to the balance between

¹⁴ The ecosystem services may not always be prone to monetary valuation (see (Giampietro 2001, Martinez-Alier 2002)).

¹⁵ Sociologists have explained this relationship from both monist and dualist perspectives (Weigert 1997). Social monists, also known as interpretivists, state "that nature and culture are not and cannot be ultimately separated in their metaphysical reality" (Fine 1992:160). This perspective suggests that understanding socio-cultural variations in natural environments necessitates "an interpretive framework that views landscapes in terms of symbols and meanings" (Greider and Garkovich 1994:5). Symbolic meanings are the key heuristic because "there are no natural meanings inherent in the world that is there" (Weigert 1997,2). Hence, this approach reduces human-environment relations to struggles over cultural self-definition, in which the natural is a mere reflection of its social representation. In the other camp, dualists argue that "*there is no simple and sustainable distinction between nature and society. They are ineluctably intertwined*" (Macnaghten and Urry 1995:217). Dualists argue that no single social science adequately incorporates both society and nature in its interpretive and explanatory frameworks. They stress the need of collaboration between social and physical sciences (Murphy 1995, Stern, Young et al. 1992) and argue in favor of a multidimensional approach in which nature "matters," and which recognizes the *embeddedness* of social action in the processes of nature. Dualists hold that purely interpretivist perspectives are incomplete because "*reality is both a social construction and a construction of nature*" (Murphy 1995:704). An example helps better illustrate this challenge. Before the arrival of the settlers during the nineteenth century, aboriginal tribes in the American southwestern desert had limited means to intervene in their natural environment. The O'otam tribe was nomadic; its traditions and language reflected the region's endemic water scarcity: "*the language of the people [tribe] was saturated with words derived from one thought: water. The great rituals of the O'otam focused on songs to pull down the clouds.*" (Bowden 1977,8). Lack of water was a *fact of life* – determined by natural conditions and reflected in cultural practices – and made water extremely valuable. The later introduction of groundwater exploitation technology in the form of the shovel, tractor, and pump by European settlers seemingly resolved the tribe's scarcity problem and reduced the relative value of the resource. Reliable and stable access to groundwater resources also made the tribe reliant on water wells and modified the symbolic role of the resource in the O'otam culture; it disrupted established social hierarchies and the tribe's social contracts. The tribe's traditional culture effectively perished as its members modified their relationship with the natural environment. The introduction of the groundwater well affected their practices as much as it reciprocally disrupted the natural balance and long-term sustainability of the regional aquifers. Bowden holds that primitive economies are "solar-fired," while modern civilizations are "fossil-fueled;" he questions the sustainability and the alleged success of "green revolutions" and "technological fixes."

the monetary market value of the goods and services they provide and the efforts necessary to produce them.

The costs associated with the management of the resources are the human capital resources required for the production of services. From this perspective, the management of the resources aims for the maximization of groundwater services. It encompasses not only practices such as the development of wells for the increased exploitation of aquifers and the installation of artificial recharge facilities, but also the implementation of regulatory frameworks that ensure the long-term sustainability of the aquifer's yield. In this sense, the management of groundwaters always entails opportunity costs: the exploitation of a particular set of services may preclude the use of others. For example, the use of groundwaters for irrigation may preclude the use of the aquifer for industrial purposes. The trade-offs that exist between different services have a "time" component as well. Different management approaches can modify the time frame within which the resource's services are available.¹⁶

E - Conclusion

The emergence of groundwater problems results from the articulation of particular groundwater exploitation patterns, from the knowledge of the factors behind changing hydrogeological conditions, and from the acknowledged social value of the resources. Groundwater problems are socio-historical interpretations: these three factors – jointly necessary conditions for the emergence of groundwater problems – structure a process of social construction. The qualitative and quantitative deterioration of the resources will only be deemed a problem worthy of public attention when intractable environmental challenges can be turned into potentially solvable problems. This is a process simultaneously determined by

¹⁶ This is commonly known as the sustainability of the resource: it points to the intuitive idea that the extraction of ecosystem services today may prevent their future availability.

the use of the resources, their understanding, and the social interpretation of the consequences of groundwater deterioration. The historically and geographically specific nature of these factors makes groundwater problems particularly dynamic. Now, in the face of groundwater problems, what factors determine the emergence of groundwater management mechanisms? What consequences does the emergence of new uses of the resources, better hydrogeologic knowledge, and the increased valuation of the resources have on existing management schemes?

III - Theories of Water Management

Theories about the factors that trigger the emergence and shape the content of mechanisms of water management tend to be rooted in one of two major schools of thought:

1. The systemic school, which posits that State power is the principal determinant of water management systems; and 2. The socio-institutional school, which argues that water management mechanisms result from processes of social interaction constrained by institutional frameworks.¹⁷ Each approach illuminates aspects that the other is incapable of or unwilling to address. These different perspectives divide the literature between studies of “water regimes” and “water governance.” Systemic analyses frame international water management regimes as a reflection of power asymmetries in the international system, with power being understood as the States’ relative capacity to get compliance from rivals in an anarchic international system. They define international water regimes¹⁸ as the formal and informal mechanisms employed by the States to regulate the use of shared waters. The approach holds that water management mechanisms reflect the power and strategic choices of the States, in response to the threats that waters pose to their security, sovereignty, and territorial integrity. Socio-institutionalists, on the other hand, frame water management

¹⁷ This distinction draws from the analytical distinction suggested by Hasenclever, Mayer, and Rittman (1997). In their terms, systemic research is based on realist theories, while socio-institutionalist research reflects neoliberal and weak-cognitivist approaches.

¹⁸ John Ruggie (1975) first formulated the concept of international regimes, defining them as "a set of mutual expectations, rules and regulations, plans, organizational energies and financial commitments, which have been accepted by a group of states" (p. 570). Successive extensions and critiques that attacked the definitional vagueness of Ruggie’s approach fostered the development of a new, more refined collective definition of international regimes. Regimes were then defined as "sets of implicit or explicit principles, norms, rules and decision-making procedures around which actors' expectations converge in a given area of international relations. Principles are beliefs of fact, causation, and rectitude. Norms are standards of behavior defined in terms of rights and obligations. Rules are specific prescriptions or proscriptions for action. Decision-making procedures are prevailing practices for making and implementing collective choice" (Krasner 1983,2). Regimes facilitate international cooperation, provide information-sharing venues and reduce transaction costs between states (Hasenclever, Mayer et al. 1997).

mechanisms as bargained coordination schemes. In general, they concur with systemic approaches that both power struggles and rational strategies determine regulatory outcomes, but emphasize the influential role of institutional frameworks and non-state actors in the emergence of water management norms. Socio-institutionalists challenge the analytical scope of systemic analyses and focus on “water governance;” they challenge the exclusive protagonism of the states in water management and explore the diverse institutional constraints that may preclude state-action, and the multiplicity of political interactions exogenous to the confines of the state that also determine how water resources are used.

The water management literature suggests that different causal mechanisms explain the emergence of management mechanisms. In order to identify relevant analytical dimensions and theoretical propositions, the next section reviews seminal debates over structural and non-structural factors shaping the emergence of water management mechanisms. It examines the role of basin geographies and state power, as well as the influence of established institutional frameworks and sub and supranational actors, in order to identify relevant analytical categories in the empirical cases that will follow.

A - Water Regimes: Reactions to Scarcity and State Power Asymmetries

The analysis of systemic factors has historically constituted the mainstream of research about water management. The majority of analyses frame the management of water resources as inevitably functional and epiphenomenal to the interests of the states. Scholars have debated in particular whether certain environmental conditions are a driver of international conflict or of international cooperation.¹⁹ Over time, however, analyses have shifted from the

¹⁹ Cooperation is a process of social interaction that denotes the existence of actual or potential conflict. The practical result of a successful cooperation process is the coordination of actions. In this sense, Keohane notes that "cooperation requires that the actions of separate individuals or organizations -which are not in pre-existent harmony- be brought into conformity with one another through a process of negotiation, which is often referred to as "policy coordination." (Keohane

preeminent study of basin geographies and water scarcity to the more general study of how those factors, among others, shape state power-asymmetries and, thus, water management mechanisms.

1) Conflict and Cooperation over Scarce Shared Waters

The realist study of water management has largely built upon the seminal empirical work of John Waterbury (Waterbury 1997), and on the classic realist theories of international relations.²⁰ During the seventies, Waterbury examined the relations of the countries of the Nile River Valley and first raised the question of “*how do hydraulics and policy intersect, and with what results for the use of the resource*” (p. 3). Waterbury noticed that water management decisions affecting the Nile River were crucial to the international relations between the basin’s riparian countries. Indeed, the Nile waters systematically put Egypt—located downstream—in a geopolitically vulnerable position relative to the other countries of the basin: upstream countries could potentially affect the flow of the River and jeopardize Egypt’s economic development and political stability. Waterbury thus theorized that regional conflict arose from the tension inherent to the contraposition of upstream claims of sovereignty and downstream demands for water security. In other terms, he observed that the geography of the Nile basin structured riparian international relations and that water management decisions, such as the construction of the Aswan High Dam, effectively

2005,51). According to Lindblom (1968), "a set of decisions is coordinated if adjustments have been made in them, such that the adverse consequences of any one decision for other decisions are to a degree and in some frequency avoided, reduced, or counterbalanced or outweighed." (p. 227). Policy coordination is thus at once an expression of a cooperation process, and an instrument functional to the minimization of international conflict.

²⁰ Wittfogel (1957) argued that the scale of waterworks required in some regions of the world fostered particular forms of government. He theorized that environmental conditions shape statecraft processes, arguing that social order reflects hydraulic landscapes. His "geographic materialist" theory first posited the existence of a causal relationship between hydrologic conditions and the institutional organization of the state.

reshaping the states' interdependencies. Waterbury's study of hydropolitics fostered research devoted to the analysis of the effects of basin geographies and water scarcity on international relations, institutions, and policy decisions. Known as the water-wars literature, these studies focus on the apparent causal relationship existing between water scarcity²¹ and social conflict (Turton 2003, Turton, Ashton et al. 2003). This approach frames water management mechanisms as the strategic means through which states ensure their access to shared waters.

Early theories asserted the existence of a "hydraulic imperative" (Wolf 1998), which refers to both the need and the mandate of the state to secure its access to water resources. The approach was originally developed and applied to explain Israeli military actions (Schmida 1983, Stork 1983, Cooley 1984, Stauffer 1996), but was later be extended by the like of Falkenmark (1989), who argued that water management regimes reflect the existence of a "water stress threshold," which marks the minimum amount of water required by the state to maintain an adequate level of food production; water-stressed countries are simply more prone to challenge and war against their neighbors for more waters. The approach prompted numerous studies detailing the quantity of water available to states located in arid zones (Elmusa 1996, Hamner and Wolf 1998, Trottier 2003, Loehman and Becker 2006, Loehman and Becker 2007). In general, these studies made no distinction between surface and groundwater, and the few studies that specifically addressed the effects of groundwater

²¹ Ohlson (1999) argues that water scarcity results from one of three factors: demand, supply, or structural inequalities between different user groups. Demand-induced scarcity is produced by the increasing pressure on the shared water resources, which can be due to demographic growth, and the increasing requirements of industry and agriculture. Supply-driven scarcity deals with the deterioration of water sources, which can occur, for example, if aquifers receiving no recharge are intensively exploited, or if waters become unfit for consumption due to contamination. Finally, structural scarcity is the consequence of the forceful confiscation of water resources by some users at the expense of others. Scarcity impacts five areas critical to socio-economic development and political stability: 1. agricultural output, 2. economic production, 3. migration patterns, 4. social segmentation, and 5. institutional stability (Homer-Dixon 1999).

deterioration on international relations corroborated the conclusions of studies dealing with surface waters (Starr and Stoll 1988, Ashley and Smith 1999).

Despite the popularity and intuitive soundness of the water wars approach, its neo-malthusian bent fueled critiques. Reviews by Libiszewski (1995) and Wolf (Wolf 1995), for example, stressed that water resources were likely neither the principal cause nor the main strategic objective of Arab-Israeli warfare. Others reviewed the validity of examining water budgets to explain the emergence of international conflict. Allan (1998) reworked Falkenmark's formula and argued that water resources are effectively transferred in commercial exchanges. Consequently, he noted, importing a ton of cereal is "virtually" equivalent to importing the corresponding quantity of water necessary to produce it; it follows that arid states have far more to gain from cooperation—and from keeping the price of cereals low in the international market—than in waging wars against each other over water.²² Reaching a similar conclusion, Richards (2001) held conflicts are triggered by not just scarcity but also the perceived injustice in the allocation of the resource. He stressed that the factors shaping perception about the reality of water scarcity are as fundamental to the development of conflicts as "*objective*" factors (Dutta and Mishra 2005).²³ In fact, critiques of the water wars hypothesis advance that shared waters are behind significantly more interstate cooperation than conflict (see for example (Wolf 1998, 1999, Jägerskog 2005, Wolf 2007). Recent large empirical studies such as that of Wolf, Yoffe and Giordano (2003) suggest that

²² Based on similar arguments, others have advocated for the establishment of objective water price-setting mechanisms that ensure the fair and efficient management of shared waters and prevent conflict (Allan 1998, Saleth, Dinar et al. 2004).

²³ Other authors advanced a different interpretation for water-driven conflicts, arguing that they are prevalent but remain unrecognized: Shiva (2002) claims that the privatization and pollution of water resources is a "war against the poor," a process that Boesen and Ravenborg (2003) and du Plessis (2000) argue will increase the likelihood of water riots, rather than international conflict.

the most commonly cited indicators linking freshwater to conflict are actually unsupported by empirical data.²⁴

The critics of the water wars hypothesis do not claim that cooperation over shared resources is the norm, or that water resources are likely to be shared equitably and reasonably by co-riparian countries. They simply stress that basin geographies and water scarcity does not necessarily trigger international conflict and that, if any causal relationship exists between the two factors, it is one that connects scarcity to international cooperation. They suggest that water problems in general and scarcity in particular foster the emergence and implementation of negotiated international water management regimes (Lowi 1993, 1993, Kliot, Shmueli et al. 1997, Dinar 2000, Kliot, Shmueli et al. 2001). Moreover, because they are focused on the availability and access to water resources in general, realist theories tend to make no distinction between kinds of water. In fact, they suggest that groundwater and surface waters play an equivalent role in politics. The water-wars versus water-cooperation debates converge in the idea that the creation of water management mechanisms is driven by the need to secure access to water resources.

2) The Hydro-Hegemony Framework: Power Asymmetries

Although early systemic theories of water management focused on the vicissitudes of the water sector, the analytical approach proved to have limited explanatory power. As noted by Daoudy, the critical theoretical shortcoming of the water wars and cooperation literature is that *“the trajectory of inter-State cooperation is largely dependent on factors other than those*

²⁴ Wolf, Yoffe and Giordano (2003) conclude that the likelihood of conflict increases not by means of scarcity, but only as one – or more – of three factors come into play: 1. The occurrence of some large or rapid change in the basin’s physical setting – typically the construction of a dam, river diversion, or irrigation scheme; 2. A change in its political setting, especially the breakup of a nation, resulting in new international rivers; or 3. The inability of existing institutions to absorb and effectively manage that change.

found in the water sector per se” (Phillips, Daoudy et al. 2006,15). Drawing from the insights of hegemonic stability theory and regime theory, more recent research holds that water management decisions are shaped by the power-asymmetries existing between states, which are only partly determined by geography and water scarcity. These studies emphasize that the study of basin geographies and water scarcity is insufficient to explain the emergence of water management mechanisms: they advocate for the closer examination of the sources and expressions of state power, as well as its effect on the management of water resources.

One of the most recent theoretical formalizations of this more encompassing approximation was operated by the London Water Research Group of the University of East Anglia in 2005, under the name of “hydro-hegemony framework” (HH) (Zeitoun and Warner 2006, Jägerskog 2008, Zeitoun and Allan 2008). According to the formulation by Zeitoun and Warner (2006), the HH framework is grounded in two critical theoretical assumptions: the existence of varying intensities of conflict and the asymmetric nature of inter-state power-relations. The first assumption is based on the observation that international relations are seldom purely conflictive or cooperative; instead they may shift over time and overlap conflict and cooperation in different issue areas (Mirumachi and Allan 2007). Hence, the framework conceptualizes international relations in a continuum that ranges from total political integration (unification) to outright war (Yoffe and Larson 2001,71).²⁵ The second assumption is that countries have different means at their disposal to fulfill their preferences, and thus may choose to obtain compliance from other states in more or less subtle ways (Frey 1993).²⁶ The framework formulates structural and circumstantial environmental conditions

²⁵ Arguably, this approach is more sensitive to situations in which, although countries are not engaged in violent conflict, peace is unstable (Zeitoun and Warner 2006).

²⁶ Daoudy (Daoudy 2005) and Turton (2005), as quoted by Zeitoun and Warner (2006), distinguish in particular two broad forms of power, *puissance* and *pouvoir*, based on their different meanings in French: "*Puissance* is potential power, power as might, such as the physical wherewithal power to

such as riparian position as components of state power. It posits that states strategically employ different expressions of power to produce water regimes and compliance; they resort to different strategies depending on their own power resources and those of the other riparians (Zeitoun and Warner 2006, 448-451).

The HH framework is rooted in Luke's (1974) three-dimensional take on power. It suggests that power is expressed through different means. The first and most apparent expression of state power is determined by a state's access to "tanks and dollars," knowledge, and its geographic position in a water basin (Strange 1987,132, Elhance 1999, Zeitoun and Allan 2008,7). Other expressions of state power are more subtle. The second form of power is the capacity to control the rules of the game, which refers to the capability of the powerful to restrict the strategic options of the weak through persuasion, influence, and authority. The third expression of power is the ability to shape the preferences of the weak via the control of their cognitive frameworks. Strange (1994) notes that: "*At this level, the strong implant their ideas, even their self-serving ideology, in the minds of the weak, so that the weak come to sincerely believe that the value-judgments of the strong really are the universally right and true ones*" (p. 176).

In essence, the HH framework argues that the States wield different forms of power in order to rule the management of water resources within their own jurisdiction and within that of riparian states. More precisely, it suggests that depending on their relative power and strategic preferences, hydro-hegemons²⁷ will exercise either positive leadership, when advocating for the integration of water resource management, or negative leadership

explode an atomic bomb, *pouvoir* is actualized power, the authority or 'powers' to stop the rocket being launched" (p. 442).

²⁷ Zeitoun and Warner (2006) define Hegemony as "*leadership buttressed by authority*"(p. 438), and note that it is different from dominance, which they define as "*leadership buttressed by coercion*." (p. 438)

(dominance), when they seek to control shared resources and contain weaker riparians²⁸ (Zeitoun and Warner 2006, 453). Positive leadership encourages the equitable and peaceful distribution of the resources through cooperation, while negative leadership leads to the inequitable consolidation of control of the shared resources and to subjacent tensions. The HH framework predicts that international conflict over shared water resources will only arise in the cases in which power-asymmetries are not consolidated, or when they shift. Moreover, it argues that changes in the forms of water management reflect shifts in the balance of power. The approach reduces water problems to just another arena of domestic policy and international relations, except that they are more relevant due to the significant threats water can pose to security, sovereignty, and territorial integrity.²⁹

B - Water Governance: The Role of Institutions and Non-State Actors

Theories that focus on the role of systemic factors normally presume international anarchy. They argue that no strong institutional framework constrains the action of the States in the international arena. The neglect of institutions adds theoretical parsimony to systemic theories, and construes water regimes as inevitably functional to the States. As stressed by Wolf and Delli Priscoli (2009), “*by focusing on the nation-state, the rich experience of building water institutions is often missed.*” Indeed, studies focusing on the processes that lead to water management mechanisms emphasize that they are often the result of uncertain

²⁸ The framework concedes that weak states may nonetheless leverage interdependence to extract benefits from the riparian’s water management decisions (Turton 2003, Daoudy 2005, Turton and Earle 2005,165).

²⁹ In general, non-systemic analyses are not agnostic to the “*kind of water*” at stake. Because they focus on the specific functional requirements of regulatory instruments (Jarvis 2006). The relative absence of international agreements dedicated to transboundary groundwaters often reflects a situation of “hydro-schizophrenia,” (Llamas 1985, Jarvis, Giordano et al. 2005) by which they implicate the inadequacy of surface water management institutions to deal with groundwaters. They stress that the resolution of groundwater problems demands in most cases either the reform of existing institutions or the emergence of new ones.

political negotiations, that negotiated agreements commonly fail to accomplish their formally stated goals, and that the mechanisms that regulate the use of internationally-shared waters are not solely implemented by the states.³⁰ The academic interest in the “moving parts” of the State and, more generally, in the non-systemic factors that shape water management decisions grew along with the increasing regulation of the water sector and the proliferation of international agreements dedicated to transboundary waters that followed the end of the First World War (Cano 1989). Interest in the institutions that effectively regulated the use of water resources at the local, national, and international levels was accompanied by theories about their emergence. Scholars challenged the presumption of international anarchy and State supremacy in hydropolitics.

The analytical shift mirrored a change in the interests of researchers—it was driven by more than theoretical dissatisfaction. The passage from state-centric power-based theories to those focusing on institutions and multi-level actors – the famous move from “government to governance” – was driven as much by the challenges to the internal validity of realist theories as by the renovation of academic research agendas driven by larger ‘tectonic’ shifts: new waves of democratization, regionalization, and the swings of the Cold War. New theoretico-analytical axioms accompanied socio-political transformations and changes in the means and ends of environmental management. Through different lenses, research highlighted new aspects of the politics of water management.

The analytical transition away from eminently state-centric theories was rooted in the notion of *governance*, and research emphasized the fragmented nature of normative-institutional systems. It highlighted the importance of the intermediate governing structures

³⁰ In fact, natural resources are managed through a myriad of mechanisms that are not sanctioned by the State: they range from community-based arrangements to private regimes (Blomquist and Ostrom 1985, Frisvold and Caswell 2000, Cashore, Auld et al. 2004).

that supplement both states and markets, and exposed the role of actors and mechanisms that are neither purely governmental nor inter-governmental in the management of water (Hufty 2007). There is, however, no collective agreement on the precise ontological and functional definition of *governance* similar to that developed for the concept of environmental regimes (see reviews by Rhodes 1997, Pierre 2000, Van Kersbergen and Van Waarden 2004), and water governance became a relatively vague term used to describe the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society (Rogers and Hall 2003).³¹ In spite of these definitional ambiguities, research employing the concept highlighted the multiplicity of actors and mechanisms that shape the way in which water is exploited and controlled. Studies of “*multilevel water governance*” examined, for example, the interactions and consequences of the competition between different government agencies dealing with water and the participation of public and private actors in decision-making processes (Worster 1985, Reisner 1986, Rogers 1993, Jouve 1995, Rhodes and Mazey 1995, Wallace 1996, Peterson and Bomberg 1999, Quevauviller, Balabanis et al. 2005).

Analyses of water governance dissect the interactions of both State and non-state actors at multiple scales and focus on the informal and formal institutions that make up water management. They are accompanied by theories that stress that international water

³¹ *Governance* was instrumental to a critique of the assumption that the European States act as unitary and rational actors in the European Union; they stressed the vertical and horizontal segmentation of the State around issue-specific constituencies in the management of water resources (Eising 2005). Governance was also employed for the analysis of the system of institutions that create, control and regulate markets: it became a tool for the evaluation of the performance of second generation economic reforms (Kiely 1998, Woods 2002). Critics contend that indexes of “good governance” operate as mere indicators of the capacity to introduce liberalization policies in developing countries (Kaufmann, Kraay et al. 2007). The concept was also employed for the qualitative evaluation of water markets and services in the sector (Smouts 1998).

management mechanisms reflect the influence of both established institutional frameworks³² and social interactions. These theories tend not to dispute the fundamental role of power in policy-making, but nevertheless emphasize the importance of the ‘process’ that leads to the implementation of water management mechanisms. They favor the analysis of non-structural factors and hold that management mechanisms are not just epiphenomenal to the preferences of the states; instead, they suggest that they are the expression of layered social interactions taking place within the “black box” of the State, which sometimes involve rationalities external to its confines. In general, contributions to the study of water governance drew from studies of the role of domestic politics by Waltz (1979) and Rosenau (1961, Rosenau and Czempiel 1992), Putnam's two-level game metaphor (1988), Keohane and Nye's complex interdependence framework (1974), Deutch and Haas emphasis on regional integration spillovers (1970), and Allison's focus on the role of bureaucracy in international relations (1971).³³

1) Institutional Frameworks: Competence, Compatibility, and Capability

A significant strand of the water governance literature examines the influence of established institutional frameworks on the emergence of water management initiatives. These studies examine formal domestic and international bureaucracies and norms, as well as the informal coordination mechanisms that constrain the use of water resources. This strand encompasses analyses of the effect that bureaucratic state agencies, international law, and informal arrangements have on water management; they also focus on the effect of normative systems on the allocation of water resources among competing users (Raustiala 1997,

³² Institutions are both the outcome of social interactions and an influence in processes of decision-making (March, 1984 #1855); they are “the rules of the game in a society or, more formally, (...) the humanly derived constraints that shape human interaction” (North, 1990 #339, 3).

³³ See also (Evans 1995, 7, Moravcsik 1997, 16).

Theesfeld 2008).³⁴ Ingram, Mann, Weatherford, and Cortner note that this approach results from “*the realization that institutional problems in water resources development and management are more prominent, persistent, and perplexing than technical, physical, or even economic problems*” (1984,323).

From this perspective, Young (2002) argues, for example, that domestic institutional frameworks shape the State’s “*competence, compatibility, and capacity*” to implement international environmental regimes (p. 98-100).³⁵ Drawing from this distinction, Scott and Milman (2010) hold that the lack of internationally-coordinated policies for the management of transboundary groundwaters along the U.S.-Mexico border reflects institutional dysfunctions. They emphasize that domestic institutional frameworks “*determine the ability of each country to engage with its co-‘aquiferian’ to address externalities from water use,*” (p. 6) and argue that the United States Federal government lacks the necessary competence to regulate the use of water resources at subsidiary levels. This fact, they note, is compounded by the incompatibility of the institutions of water governance in the U.S. and in Mexico and the limited capacity of the Mexican government to effectively regulate the resources. They conclude that the development of formal arrangements for the governance of transboundary groundwaters between the two countries is unlikely. This interpretation, which stresses the political hurdles produced by institutional dysfunctions, echoes the conclusions of Mumme (2005), Ingram (2000), Turner (2003), and Hamlyn (2001), among others. It suggests that

³⁴ Institutional mechanisms normally prevent the States from bridging the legitimate boundaries of their own power (Keohane and Grant 2005: 30). Constructivist scholars have noted that institutions accommodate more than state interests: they redefine agency, authority, leadership, and even citizenship (Finnemore and Sikkink 1998, Hurd 1999, Barnett and Finnemore 2005, Alter 2009).

³⁵ Competence being the State’s authority to institute specific management decisions; compatibility, the possibility of aligning domestic institutional frameworks to international water management objectives; and capacity, the availability of the material and symbolic resources necessary for the implementation of the agreements.

institutional dysfunctions operate as barriers for the international governance of shared groundwaters;³⁶ it posits that the flaws in the design and the operation of water management institutions prevent the formalization of international water management arrangements. These flaws, as noted by Scott and Milman (2010), arise not just from errors in the making of policy, but may also arise over time as the priorities, the instruments, and the issues of water governance evolve.

This strand of research emphasizes the disruptive effect of institutional *polycentrism* and *mismatches*. Polycentrism describes gaps and overlaps in the jurisdiction of water governance authorities; it refers to the institutional redundancies and the unclear allocation of decision-making authority that foster competition and conflict between water governance agencies (Tang 1991, Folke, Hahn et al. 2005, McGinnis 2005, Feldman 2006).³⁷ Institutional mismatches, on the other hand, denote the potential incompatibility of established water governance normative systems (Turner, Hamlyn et al. 2003, Saleth, Dinar et al. 2004, Sprouse 2005). These mismatches are indicated by the absence of functional-equivalent structures in riparian states and create hurdles for the development of internationally-coordinated water governance approaches because they reduce international water governance negotiations to the specification of general goals and principles of water management (Blomquist, Heikkila et al. 2001, Huitema, Mostert et al. 2009). These approaches suggest that as the size and complexity of the institutional framework governing water resources increases, the likelihood

³⁶ Rational choice theorists generally argue that institutions are reformed only if dominant actors can secure increased payoffs from the process (North 1990). They note that actors will normally support reforms if they favor their interests. However, the outcome of processes of institutional reform is often uncertain in the context of complex institutional frameworks. Given the uncertainties inherent to reform processes, Pierson (2000, 2004) claims that institutional systems are embedded with conservative tendencies.

³⁷ In general, the relations between the institutions of water management may be conflictive as well as synergic, but either situation has an impact on the effectiveness and quality of domestic water governance (Oberthur and Gehring 2006, Gehring and Oberthür 2008, Young, King et al. 2008).

of significant institutional reforms and the emergence of transformative formal governance mechanisms decreases (Lach, Ingram et al. 2004).

2) Non-State Actors in Water Governance

An alternative strand of research about water governance has examined the influence of non-state actors in water politics: the role of international organizations and of activists in the emergence of new norms of water governance. These studies generally argue that a wide array of stakeholders besides the States, ranging from international organizations to networked water experts and social movements, participate in the creation and reform of water governance mechanisms. They hold that water governance results from the interaction of the State with non-state actors.³⁸ Under these theories, institutions are never a neutral field for social interaction; rather, they are embedded with the preferences of dominant coalitions and operate as an arena that shapes socio-political interactions.

The analysis of the effect of social interactions on water governance decisions is often rooted in constructivist approaches, which stress that political change is inextricable from *“norm entrepreneurialism, norm cascades, diffusion processes, and social ‘tipping points’ in which some sort of critical mass is attained (or not attained, as the case may be, although negative cases remain infrequent in the literature)”* (Ignatova and Conca 2010). These studies argue that although established institutional frameworks can restrain normative change, in order to understand normative change, one has to look at the social interactions (Checkel

³⁸ Scholars have recently argued that non-state actors are also capable of fostering “private” regimes, which are relatively autonomous from the State. These regulatory frameworks are rooted in common standards and are operational in sectors ranging from insurance to forestry (Cutler, Haufler et al. 1999, Brink 2002, Cashore, Auld et al. 2004). Governed by the norms produced by networked members, these non-state regulatory mechanisms regulate fisheries (the Marine Stewardship Council and the Marine Aquarium Council), sweatshop labor workers’ rights (Social Accountability International and the Fair Labor Organization), and global coffee production (Fair Trade Coffee and Rainforest Alliance certified coffee).

1998, Finnemore and Sikkink 1998, Keck and Sikkink 1998, Risse-Kappen, Ropp et al. 1999, Checkel 2007). These perspectives do not reduce institutional frameworks to the ‘context’ in which actors interact. They recognize the biases and compromises ossified in the normative frameworks that mediate interactions. Yet, they hold that the analysis of the ‘weapons’ and the modes of interaction of political actors are pivotal to understanding the reform of established institutional frameworks: some emphasize the role of international organizations, while others focus on the role of domestic and transnational social networks.

a) International Organizations

Studies that focus on international organizations (IOs) argue that they have an overt influence on the policies adopted in some countries, either through conditionality (Killick, Gunatilaka et al. 1998) or through other less explicitly coercive means (Culpeper, McAskie et al. 1997). To illustrate the protagonism of international organizations in water politics, researchers have, for example, pointed to the influence of the principles of *Integrated Water Resources Management* (IWRM) in domestic decision-making processes (Krause Hansen, Salskov-Iversen et al. 2002, Alkoby 2008, Langridge 2008). The principles of IWRM “*promote the coordination of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems*” (Snellen, Schrevel et al. 2004). Scholars emphasize that these principles were carefully crafted in the context of international conferences as means to encourage the sustainable management of water resources at the global level, and that they currently structure most water governance initiatives (Wouters and Vinogradov 1998, Zekster and Everett 2000, Mukhtarov 2007, Wouters 2008, Varady, Meehan et al. 2009). They suggest that the integration of these principles in water management projects and institutions are indicators of the effectiveness and political influence of international organizations. They stress that although the approach has been practiced in various forms since at least the

nineteen-twenties in the United States and in Europe, its formal formulation in 1956 by the United Nations (UN) turned the approach into the main paradigm against which domestic water management and protection schemes are evaluated (White 1998, Burchi 1999, Burchi, Mechlem et al. 2005).³⁹

These theories generally support the notion that international organizations are not just agents of the State and explore the organizational features and mechanisms through which these actors engage and influence the States (Keck and Sikkink 1998, Wendt 1999, Muller 2000, Barnett and Finnemore 2005). Barnett and Finnemore (2005) explain the influence of IOs by arguing that they are bureaucracies and that, as such, enjoy four sources of authority: 1. Delegated authority, through an explicit mandate from the member-states and conditional on their performance; 2. Expert authority, derived from their control of specialized policy-relevant information; 3. Rational-legal authority, because they are supposed to operate according to objective impersonal rules; and 4. Moral authority, resulting from their claim to represent the values and interests of the community rather than the partial, self-seeking interests of individual States (p. 20-25). These sources of authority offer IOs a certain degree of autonomy vis-à-vis the States and grant legitimacy to the norms that they produce. International organizations exert their influence through the formulation of prescriptive discourses embedded in codified international laws, water conventions, and non-binding recommendations (Wouters and Vinogradov 1998, Trottier and Slack 2004). Arguing in a similar vein, Alter (2008) suggests that IOs may act as “trustees,” to whom the States have

³⁹ The UN Economic Commission for Europe (UNECE) has, for example, fostered the IWRM approach through the formulation of Charters and non-binding recommendations (Boisson de Chazournes and Salman 2005, UNECE 2007). The UNECE Water Convention, adopted in Helsinki shortly before the 1992 Rio Summit, provided a general legal framework for water management that has been applied to bilateral or multilateral agreements between European States, such as the Danube River Protection Convention in 1994, the 1999 Rhine Convention, and the European Union’s Water Framework Directive (Barraqué 1995).

willfully endowed legitimacy. The States delegate power to IOs in order to ensure their relative autonomy and their capacity to influence State behavior (Alter 2008, 38-39).⁴⁰ In other words, these theories generally posit that the IOs are influential and autonomous political actors because the norms that they create and mobilize in the public arena are deemed legitimate by other political actors (Hurd 1999). In this context, legitimacy is “*the normative belief by an actor that a rule or institution ought to be obeyed;*”⁴¹ it is “*a subjective quality, relational between actor and institution, and defined by the actor's perception of the institution*” (p. 382). The perceived legitimacy of IOs is what facilitates the internalization of the rules that they produce and advocate.

⁴⁰ Critiques of the approach are rooted in the principal-agent theory and challenge the supposed autonomy of international organizations. Hawkins, Lake, Nielson, and Tierney (2006) argue, for example, that principal-agent theory states that international organizations are “agents” delegated by State “principals” to perform specific tasks. They stress that the States control the budget, the mandates, and appointment of the agents, and thus retain control over international organizations. In this sense, they remain proxies for the preferences of the States (p. 7).

⁴¹ Hurd argues that compliance may be produced through three mechanisms, Coercion, self-interest, and legitimacy –the Weberian ideal types for modes of social control. Coercion refers to a relation of asymmetrical material power among agents, applied to changing the behavior of the weaker agent. Acquiescence is obtained through fear. It is a relatively simple form of social control, but it is cost-inefficient to the power-wielder. Self-interest suggests that any rule followed by individuals is the result of an instrumental and calculated assessment of the net benefits of compliance versus noncompliance, with an instrumental attitude toward social structures and other people. The task of the governing agent is to structure incentives so that community members find compliance to be the most rationally attractive option. Under this model, social interaction is an exchange, and social obligations are contracts: individual decisions are calculated to maximize returns, and organizations are pillars of accumulated principal-agent contract relationships. The internalization of norms happens in a decentralized, rule-by-rule basis, as actors progressively accept the legitimacy of the decisions of international organizations, or as actors develop the identity of a “*rule-following agent.*” Such an identity makes the questioning of any particular rule unnecessary except in unusual circumstances. The strategic nature of the State’s behavior only manifests itself when the State decides to break the rules.

b) Social Networks

Studies that emphasize the role of the civil society in international water politics tend to explore the features and influence of social networks.⁴² Borgatti and Foster (2003) argue that the recent proliferation of network research in organizational analyses reflects a “*shift away from individualist, essentialist and atomistic explanations of policy-making toward more relational, contextual and systematic understandings*” of the process. Network studies emphasize the relational nature of water politics, the importance of social participation in policy processes, and the unique role of scientific expertise in politics. The seminal research about the influence of networks in water governance examined the influence of social relations in policy-making processes.

Scholars demonstrated, for example, the pivotal political influence of the *policy networks* that result from the fluid issue-based alliances of government agencies with non-state actors (Dowding 1994, Reinicke, Deng et al. 2000). *Insiders* of the policy-making process by definition, these networks have been described as *communities of practice* that promote the reproduction of operational standards across borders on the basis of common interpretations of the policy-problems (Brown and Duguid 1991, Wenger and Snyder 2000),

⁴² Barnes (1954) crafted the term “*social network*” to systematically denote patterns of ties that cut across concepts traditionally used by the public and social scientists, such as groups and social categories. It is a useful metaphor to connote complex sets of relationships between members of social systems. A social network is generally defined as “*a finite set of actors and the relation or relations defined on them*” (Wasserman and Faust 1994). Network analyses argue that the members of social networks are bound together by relational attributes, being ties such as shared values and “*principled beliefs*,” and not by the isolated features of the actors. Similarly, Jenkins-Smith and Sabatier theorized that belief systems are composed of a “*deep core*” of normative or ideological beliefs, a “*policy core*” of specific commitments, and non-essential details (Jenkins-Smith and Sabatier 1994). They stress that advocacy coalitions aggregate actors and organizations at different levels of government who “*share a particular belief system – i.e., a set of basis values, causal assumptions, and problem perceptions – and who show a non-trivial degree of coordinated activity over time*” (Sabatier 1998,139). The constructivist approach challenges the pre-existence of the belief systems structuring social networks and instead frames social networks as ‘*constructed narratives*’ produced by the members’ interaction and communication (Hajer 1997).

and thus facilitate policy-transfers and the international convergence of water policies (Dolowitz and Marsh 2000, Freeman 2006). Other studies, reformulating social movements as *advocacy networks*, stressed that non-governmental organizations and activists have an influence on political processes even as “outsiders”⁴³ in the decision-making process (Josselin 2001).⁴⁴ Nonetheless, analyses of advocacy networks emphasize the importance of “inclusion” for the success of water governance initiatives; this is because, as noted by Brich, Jansky, Nakayama, Salewicz, and Cassar (2005), “*although the time, financial, and personnel costs associated with public involvement can deter some [government] agencies...the costs of failing to involve the public generally are greater—and sometimes much greater*” (p. 6). Indeed, the exclusion of advocacy networks from policy processes may disrupt the implementation of governance decisions. Empirical research illustrates the success of these networks in preventing the construction of socially and environmentally disruptive water infrastructure projects in Asia and in Latin America (Conca 2002, Khagram 2004, Conca 2006, Berry and Mollard 2009, Hoogesteger van Dijk 2012). Still, advocacy networks are not necessarily adversaries of the State.

In addition to direct actions, advocacy networks may also influence policy-making on the bases of their expertise and scholarly knowledge; they can employ knowledge as means to challenge the legitimacy of existing institutional frameworks. This is the famous case of epistemic communities, which Haas (1992) defined as “*a network of professionals with*

⁴³ Although autonomy from the States is a central feature of these networks, its assessment is empirically challenging. The clear-cut definitional antagonism should be taken with precaution because, as emphasized by Halliday (2001), social movements often play a critical role in the constitution and action of the States. Moreover, it begs for the distinction of *participation* and *influence* in policy processes: one does not imply the other.

⁴⁴ The members of these networks are empowered with material and symbolic resources that they mobilize strategically in order to influence State decisions. Moreover, because they are not bound by national borders, they often rely on transnational relations to exert pressure on the States (Frieden 1991, Keck and Sikkink 1998, Halliday, Josselin et al. 2001, Josselin and Wallace 2001:253).

recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue area” (p. 3). The members of epistemic communities influence the policy-making process by “*articulating the cause-and-effect relationships of complex problems, helping States identify their interests, framing the issues for collective debate, proposing specific policies, and identifying salient points for negotiation*” (p. 2). This is also the case of *Knowledge Networks* (Stone and Maxwell 2005) which, unlike epistemic communities and communities of practice, actively explore the most effective uses of research, data and analysis for the formulation and implementation of policy; traversing scholarly and policy subject fields to function as brokers of new policy (Stone 2002, Stone and Maxwell 2005). Knowledge networks are neither strictly insiders nor outsiders in the governance process, these networks are composed of “*professional bodies, academic research groups and scientific communities that organize around a special subject matter or issue.*” They influence policy through “*a system of coordinated research, study (and often graduate-level teaching), results dissemination and publication, intellectual exchange, and financing across national boundaries*” (Parmar 2002, 13) and produce legitimate discourses at the interface of power and knowledge that naturalize specific ways of thinking and normalize actions (Stone and Maxwell 2005).

Whether they deal with the interactions of IOs and the states or the influence of non-state actors in policy-making, studies of water governance generally emphasize that water governance is the result of a *process*. This approach is rooted in the notion that despite power asymmetries among actors, and institutional constraints that reshape strategic action, environmental policy and norms are derived from layered social interactions. They challenge the exclusive protagonism of the State in water politics through the exploration of the bargaining processes that underlie the formulation of new policy and the reform of established water management mechanisms.

IV - Analytical Framework

Given the diversity of analytical approaches available to deal with water resources, researchers interested in the fate of groundwaters have to deal with what the French call “*l’embarras du choix*,” the challenge of choosing among seemingly equally valid options that nonetheless focus on significantly different aspects of water management. At this point, while the danger lies in the arbitrary choice of a theoretical approach, the greater challenge lies in the formulation of an analytical framework for empirical data that can constructively articulate existing theoretical contributions. The development of such an approach needs to illuminate a variety of potential explanatory causes and to verify their relative empirical usefulness. Rather than instrumental to testing the validity of theories formulated to deal with surface water resources with respect to groundwaters, the approach serves the formulation of a more encompassing theory for the explanation of the emergence of transboundary groundwater management; capable of addressing the factors that explain why groundwater resources have so long been ignored and the design and implementation of alternative approaches to the management of the resources.

The analytical and conceptual framework suggested here for the analysis of cases of transboundary groundwater management draws from the reviewed contributions to the literature dedicated to water management. It considers the possibility, advanced by systemic theories, that transboundary groundwaters can be understood as traditional interstate issues and that the management of the resources is influenced by structural factors. It also echoes socio-institutional considerations and emphasizes that the formulation and implementation of water management mechanisms is riddled by established institutional frameworks and by the interactions of state and non-state actors. This approach frames groundwater problems as yet another expression of international political tensions, and management mechanisms as the

means through which those tensions are appeased. It holds that the absence of groundwater management is the result either of the absence or ignorance of the threats posed by exploitation of the resources, and that geopolitical power struggles, rational calculations, and cognitive factors determine particular approaches to environmental management.

This approach presumes that the recognition of transboundary groundwater deterioration as a problem depends on three factors: 1. The actual or projected use of the resources, which depends on the demand of the resources and the availability of technology for their exploitation, 2. the availability of knowledge about the resources informing about the eco-systemic functions of transboundary aquifers, which include the hydrogeologic features of the aquifers, as well as the reasons behind the deterioration of the resources, and 3. The social valuation of the resources, which is determined by the market value of the resources and the costs associated with their management. I argue that the articulation of these three factors shapes the interpretation of the quantitative and qualitative deterioration of groundwater resources as a source of socio-political tensions: groundwater problems.

Second, I submit groundwater governance mechanisms are determined by both systemic and socio-institutional factors. Systemic factors –the power-asymmetries that exist between sovereign States– point to the position of the riparians in the shared basin, the relative scarcity of water resources, and the meteorological and climatic features of the environment;⁴⁵ but also to the relative control of the riparian states of explicit resources of political coercion and more subtle tools, such as the control over the rules of the policy-making process and the overarching cognitive frameworks according to which the States

⁴⁵ Despite the common conceptualization of transboundary groundwater resources as common pool resources, the users of shared aquifer often have the possibility to exclude competitors from accessing the resources. Limits to the access to the resources can be imposed through quantitative and qualitative interventions on shared aquifers.

determine their preferences, and determine interstate power-asymmetries. Socio-institutional factors, on the other hand, point at the institutional barriers and political drivers of new groundwater management initiatives. These factors point at the institutional dysfunctions which may undermine the emergence and implementation of groundwater governance initiatives; they include the relative domestic polycentrism of the frameworks of water management, the incompatibilities and mismatches that exist between the institutions in place in the states sharing transboundary groundwaters, and the relative flexibility of established mechanisms to deal with the problems associated with groundwaters. In addition, the framework considers the influence and role of non-state actors in the political process; in the strategic framing of groundwater problems as policy-problems and in the mobilization of legitimate challenges to established approaches to the use of groundwater resources. This encompassing analytical approach (summarized in the table that follows) is instrumental for the analysis of cases of groundwater management, but is also a useful guide to organize the diverse contributions to the water management literature.

Finally, I contend that systemic and socio-institutional factors determine whether transboundary groundwaters are the object of coordinated or unilateral management schemes. Coordinated mechanisms are formal and informal norms and principles that ensure the harmonization of exploitation and mitigation actions. They can be either enforceable, when the mechanisms require authoritative oversight, or self-enforcing, when the implementation of management provisions is ensured by the stakeholders in each riparian country. The unilateral management of the resources, on the other hand, is the exploitation of the resources with without cooperation or coordination. The management of transboundary groundwater resources will fall under one of these types.

Table 1: The Analytical and Conceptual Framework			
1. The recognition of transboundary groundwater problems			
Exploitation	Due to: <ul style="list-style-type: none"> • Demographic and Economic Growth (i.e. conflicting or mutually-exclusive uses of groundwater) • New technology (i.e. drilling, pumping and prospecting) 		
Hydrogeology	Identification of eco-systemic functions: <ul style="list-style-type: none"> • Aquifer features (i.e. storage, recharge, yield, etc.) and the influence of contextual environmental conditions • Sources of groundwater depletion/deterioration (i.e. Anthropogenic, Natural) 		
Social Valuation	Determined by: <ul style="list-style-type: none"> • The market and symbolic value of groundwater services resources • The cost of management 		
Given patterns of exploitation, knowledge of hydrogeology and the valuation of the resources...			
2. Are there Problems?			
YES		NO	
Always localized and frequently transboundary, resulting in social tensions i.e. Quantitative (Overdraft), Qualitative (Pollution), Other (Well Interference/Soil Subsidence)		Due to either absence or <i>ignorance</i> of the problems	
Given the groundwater problems...			
3. Factors that shape the emergence of management mechanisms			
Systemic factors	<i>Power Asymmetries</i>	Determined by: <ul style="list-style-type: none"> • Geography and environmental conditions (i.e. riparian position, scarcity, etc.) • Power in its three dimensions (i.e. 'tanks and dollars,' control of the rules of legitimate political interaction, control of the 'paradigms') 	
Socio-institutional factors	<i>Established Institutions</i>	Barriers resulting from <i>Dysfunctions</i> : <ul style="list-style-type: none"> • Domestic polycentrism • International incompatibilities and mismatches • Flexibility of institutional frameworks to new knowledge and information 	
	<i>Social Interactions</i>	Between State and Non-State actors. It is driven by: <ul style="list-style-type: none"> • The legitimacy of non-state actors (i.e. IOs, advocacy networks, etc.); The influence of policy and advocacy networks 	
4. Two Approaches to Transboundary Groundwater Management			
Type of Management	Coordinated		Unilateral
	<i>Self-enforcing</i>	<i>Enforceable</i>	<i>Unilateral Management</i>
Management Mechanism	<ul style="list-style-type: none"> • Informally coordinated policies at the local level aimed at specific problem-resolution • Framework agreement focused on the protection of state-sovereignty 	<ul style="list-style-type: none"> • Formal binding agreement; a "contractual" arrangement between the riparian countries governing the local-level management of the resources 	<ul style="list-style-type: none"> • No formal coordination mechanism • Limited bilateral dialogue

A - Ideational Factors as an Ariadne's Thread

In order to navigate the maze of possible explanations for water management and bridge the gaps between theoretical assumptions and analytical scopes that exist between the theories that underlie the analytical framework, this research relies on the analysis of ideational factors in the formulation of groundwater problems and in the emergence of management mechanisms. This is because Although the causal nexus between ideational factors and the making and implementation of policy is often ambiguous (Braun and Busch 1999), these factors often are implicitly transversal to the different theories of water management. When explicitly addressed, it is from different standpoints that Bieler (2001) generally categorizes as *cognitive* and *constructivist*.⁴⁶

Cognitive approaches advance the notion that ideational factors have a causal impact on political processes because they are embedded in institutions – in the form of procedures, organizational rules and mandates – and because new ideas can challenge the legitimacy of established institutional systems.⁴⁷ Ideational factors are presented as separate from the interests

⁴⁶ Bieler suggests that the analysis of ideas should also consider a third possibility, which he calls neo-Gramscian. He claims that the 'organic ideas' and 'organic intellectuals', first identified by Gramsci, legitimize social hegemony and shape identity (Gramsci, 1971, 5, quoted in Bieler 2001, 99). From this perspective, the content and expression of ideas are determined by ideological and material hegemony: recognized 'truths' depend on the capacity to gain control over the material resources and over networks. This approach runs parallel to post-modern critiques that argue discourse, symbolism and language have an independent influence on politics because they are embedded in knowledge—in the form of scientific treatises, scholarly books, NGO advocacy and intellectual debates.

⁴⁷ Goldstein and Keohane (1993) explain that ideas influence policy through three causal pathways: 1. As a "road map," because they determine or precise the relationship between goals, alternative strategies, and outcomes; 2. As a "focal point," because they helps the actors choose from seemingly equally efficient options; and 3. Through "institutionalization," when ideas become embedded in institutions and influence behavior over time.

of the actors; they operate as tools or ‘commodities’ at their disposal.⁴⁸ The principal corollaries of the approach are that an idea’s cogency—its intrinsic force, logic, and viability—is as at least as important as the way in which it is mobilized in the policy-making process (Jacobsen 1995), and that access to knowledge and information is an expression of political power. From this perspective, institutions reflect the successful mobilization of the *bias* of political actors; the triumph of particular interpretations of the policy-problems (Jasanoff 2005, Conca 2006). New ideas have the power to modify the nature of the problems that policy seeks to redress, as well as the means through which it may achieve these goals (Blyth 2002).⁴⁹ The institutions of environmental governance are thus always potentially vulnerable to new interpretations of the problems (Haas, Keohane et al. 1993), as well as to the emergence of new political priorities (Haas 1999). These contributions emphasize that the means and ends of environmental management may change dramatically as new authoritative “truths” and new knowledge emerge.

From this perspective, political struggles revolve more around the political formulation of the policy problem than the selection of the ‘right’ solution (Bardwell 1991; Stone 1989). This is because, as noted by Cobb and Elder, “*how an issue is defined...will have important bearing on the nature and eventual outcome of a conflict*” (1983,96).⁵⁰ In fact, the political formulation of

⁴⁸ As noted by Stone (2002), “[P]olicy-making is a battle of ideas and knowledge is a weapon in the service of material interests” (Stone 2002, 97); or, in the words of Howlett and Bennet (1992), “*knowledge and information should be seen as one more resource that identifies the powerful from the non-powerful. Information about public policy is not utilized in a neutral or depoliticized fashion.*” (p. 291).

⁴⁹ In rationalist terms, new ideas may delineate alternative programmatic strategies through which the dominant actors can ensure increased payoffs (Campbell 1998, 385-6 and 389-90). They foster reform because they have the power to reshape the preferences of the actors and challenge the legitimacy of existing institutional frameworks (North 1990, 363, Hall and Taylor 1996, 937 and 595).

⁵⁰ In the case of groundwater policy, for example, the institutions appropriate to deal with a limited supply of water may differ significantly from those created to deal with the problems of excessive water demand.

the problems—their framing—establishes the politically relevant features of a phenomenon; it entails the composition of ‘causal stories’ that determine responsibilities among stakeholders and the urgency of policy (Stone 1989: 282). This should not come as a surprise, since political actors are normally aware of the practical connection that exists between the definition of policy problems and the promotion of their interests (Bardwell 1991). They purposely advocate for their own particular definitions of policy issues in the political agenda: “*policy images*” through which they challenge existing institutional arrangements and political agreements (Baumgartner 1993; Haas 1991). In this light, the processes leading to the emergence of environmental management mechanism are essentially ideological contests. As noted by Stone (2002), the contest of ideas and battles to control the terms of policy debate reveal that the utilization of knowledge –the determination of ‘legitimate’ knowledge – is the essence of politics.

Research rooted in constructivist conceptualizations⁵¹ refuses to objectify ideational factors. It challenges cognitive approaches along two main lines: first, in the implicit acknowledgement that the preferences of the actors are determined prior to the policy-making process, which reduces the power of ideas to their capacity to manipulate audiences. Second, because the conceptualization of ideational factors as causal mechanisms obscures their role outside the restricted realm of policy discussions. In short, in its tendency to focus on the observable effects of ideational factors, the perspective misses the social and structural quality of ideas (Yee 1996,102). Constructivists suggest that interests – specific policy preferences – are

Although the fundamental issue may be the same, the different framing of the problem implies different management solutions, such as the construction of new water catchment infrastructure or the installation of a new water-pricing scheme.

⁵¹ Adler defines the approach: “*constructivism is the view that the manner in which the material world shapes and is shaped by human action and interaction depends on dynamic normative and epistemic interpretations of the material world*” (Adler 1997,322).

determined *in the context* of policy-making. They criticize the distinction of ideational factors and interests. Instead, they suggest considering ideas as held collectively; framing political change as the result of new inter-subjective knowledge, common understandings, and shared identities (Wendt 1991, Hommes, Vinke-de Kruijf et al. 2009).

From this perspective, ideational factors operate as symbolic technologies, which “*enables us to see that they are shared forms of practice, sets of capacities with which people can construct meaning about themselves, their world and their activities*” (Laffey and Weldes 1997,210). Wendt (1999) suggests focusing simultaneously on “*identities and interests, the reproduction and/or transformation of which is a key determinant of structural change*” (p. 394); he notes that “*it is through reciprocal interaction ... that we create and instantiate the relatively enduring social structures in terms of which we define our identities and interests*” (p. 406). This approach is common in studies that deal with the social construction of policy problems (Aguilera-Klink, Perez-Moriana et al. 2000, Burr 2003), policy belief systems (Hurwitz, Peffley et al. 1993, Peffley and Hurwitz 1993, Weible 2005, Ainuson 2009) and identity in conflicts over water resources (Laurie and Marvin 1999, Frueh 2003, Laurie 2011). Perhaps most notably, constructivists emphasize that ideational factors are not instruments, nor are they simply a “theoretical filter” (Ruggie 1998, 867-8); they understand the relationship between ‘problems’ and ‘solutions’ differently (p. 869). They suggest that the analytical distinction between the problems and the solutions is spurious. As emphasized by Hall (1989) “*when an evocative set of ideas are introduced into the political arena, they do not simply rest on top of the factors already there. Rather, they can alter the composition of the other elements of the political sphere, like a catalyst or binding agent that allows existing ingredients to combine in new ways*” (p. 367). The paradigmatic shifts that revolutionize the understanding of the goals of

policy may therefore echo struggles taking place well beyond the scope of policy-making arenas (Hall 1993, 287); new ideas have an impact on the ‘interpretative frameworks’ of policy –the shared understanding of the problems that policy seeks to redress, its means, and its goals.

These approaches highlight that groundwater problems and, thus, the management mechanisms designed to cope with them, are not necessarily independent from the socio-political context in which they are formulated. It emphasizes that groundwater problems may reflect particular relationships between the social and the natural, which are not determined individually by neither the use of the resources, the understanding of the resources, nor their socio-culturally specific valuation, but by the particular articulation of those factors. It suggests that the formulation of groundwater problems and the emergence of groundwater management policies are intimately intertwined. In fact, the analytical distinction of ‘problems’ and ‘solutions’ suggested in the analytical framework should not be confused with a functionalist interpretation of the management of the resources; the argument is not that groundwater management results from the existence of problems, but rather that the formulation of groundwater problems is a constitutive element of the political process, and one that requires further attention. Groundwater problems do not necessarily lead to the emergence of management mechanisms, but they are pivotal in the political processes that determine whether new management mechanisms are established.

This research recognizes the value of the cognitive approach, but emphasizes the usefulness of the constructivist rationale for bridging the gap existing between systemic and socio-institutional theories of water governance. Accordingly, while it acknowledges the role of ideational factors as power resources in the implementation of water management mechanisms, it

highlights their constitutive role in the emergence of stakes and actors involved in and driving the policy-making processes.

B - Research Design and Case-Studies

As hinted in the introduction, the research design for empirical research reflects what Maxwell (2005) denominates an interactive model: "*the activities of collecting and analyzing data, developing and modifying theory, elaborating or refocusing the research questions, and identifying and dealing with validity threats*" occurred simultaneously, each element influencing all of the others (p. 3). This qualitative approach was instrumental to the emergent nature of groundwater management: the constant dialogue between concepts, theories, and empirical data served the formulation of a viable conceptual and analytical framework and grounding a theory about the factors that drive groundwater management. It favors a small-n comparison due to the potential complexity of alternative pathways to the emergence of groundwater problems and to the implementation of management mechanisms. A hypothetico-deductive approach would have been too restrictive to deal with the emergent phenomenon of groundwater management; as stated by Homer-Dixon, "*during early research in a new field, especially if the subject matter is highly complex, hypotheses are liable to be too crude to support testing that involves quantitative analysis of a large number of cases*" (Homer-Dixon 1999, taken from George and Bennett 2005). Instead of assuming independent variables consistently jointly-sufficient across cases, I explored a maximum of potential explanatory factors.

The case-studies were chosen according to their ability to highlight the factors that shape significantly different approaches to the management of the resources in different social, political and economic contexts; the elements that drive the social recognition of groundwater problems

as a topic worthy of political attention, and that shape management strategies. Choices were rooted in exploratory interviews and revisions of secondary sources, but also in practical considerations regarding field work objectives. I selected cases in which I could communicate directly with interlocutors, and where I considered I could ensure access to information about the politics of water management.⁵² For the analysis of empirical data, I inductively trace the processes (George and Bennett 2005) that led to the implementation of groundwater management mechanisms. The presentation of the cases is thus chronological; a strategy instrumental to the dyachronical identification of the factors responsible for the entry of groundwater into the political agenda in each case. The "contrast of contexts" (Skocpol and Somers 1980) highlights the distinctive features in the cases –the particular "fault lines" that drive groundwater governance.

The analysis of the cases is rooted in both secondary sources and extensive semi-structured interviews with knowledgeable interlocutors (see list of transcribed interviews in the Appendix). I derived causal factors from the triangulation of sources of information and “overlapping policy narratives” (Court and Young 2005) –through the systematic analysis of their discourses– as well as with the secondary sources.⁵³ This hypothetico-inductive approach served the formulation of a ‘grounded’ theory about the emergence of groundwater management mechanism that reflects the concerns of both social scientists and practitioners. This approach maximizes the usefulness of

⁵² I rejected cases dealing with situations of violent conflict and located in geographic areas in which I would not be able to engage directly with my interlocutors.

⁵³ Testimonies are presented in the Annex within the larger context of the discourse of the actors, in order to defend analytical interpretations.

the research's findings for both management experts and analysts; hopefully, it adds experiential credibility and 'understandability' to the results (Bolster 1983, quoted in Maxwell 2005, 8).⁵⁴

My cases are: 1. the Génévois Aquifer (France –Switzerland), 2. the Hueco and Mesilla Bolsón Aquifers (Chihuahua, Mexico – Texas and New Mexico, USA), and, 3. the Guaraní Aquifer System (Argentina – Brazil – Paraguay – Uruguay). The Génévois Aquifer is the object of a formal mechanism aimed at the coordinated management of the resources, albeit rooted in a contractual arrangement between local authorities. The Hueco and Mesilla-Bolsón aquifers management is not the object of coordinated policies between the U.S. and Mexico. Here, despite a common understanding of the challenges associated with the deterioration of the resources, local level political authorities have opted for unilateral management strategies. The management of the Guaraní Aquifer System is the object of informal local level policies, and of a framework agreement signed by the riparian countries.

The analysis of the cases seeks to capture the processes that lead to the formulation of groundwater problems and the emergence of the management mechanisms crafted to deal with them; it suggests that the translation of groundwater deterioration into policy-problems is inseparable from the process that leads to the determination of viable approaches to groundwater management. In essence it examines groundwater problems as determined by demand, the availability of information about hydrogeological conditions, and the social valuation of the services provided by the resources; and management mechanisms as reflections of structural power asymmetries embedded and shaped by institutional frameworks, and by the actions and interactions of state and non-state actors.

⁵⁴ This is what Robert Stake (1995) calls the naturalist validation through vicarious experience.

V - The Génévois Aquifer

A - Introduction

This chapter examines the different roles of ideational factors in the political process that led to the co-management of the Génévois Aquifer shared between Switzerland and France (See Figure below).⁵⁵ The management of the Génévois Aquifer constitutes the first documented case of formalized cooperation for the joint management of transboundary groundwaters and remains to this day one of the few examples of this approach. The case demonstrates that formal mechanisms can be used effectively to manage shared groundwaters, which has been instrumental to the development of international guidelines for the co-management of transboundary aquifers at the global level (Yamada 2004). Is it possible to explain the implementation of a joint-management mechanism for the Génévois Aquifer solely through the analysis of systemic factors? Alternatively, are socio-institutional factors sufficient to explain the emergence of the formal co-management approach? In this case, the exclusive analysis of power asymmetries and of institutional frameworks does not adequately illuminate the political process and the actors involved in the process. The social recognition of groundwater problems led to their entry of the aquifer's problems into the political agenda, and fostered the implementation of policies for their resolution. Scientific knowledge and the actors responsible for its production played a significant, yet changing, role in the different stages of the policy process. Nonetheless, original scientific assessments and local joint problem-framing effectively reshaped interests and challenged the legitimacy of established institutional frameworks. The point of this chapter is to

⁵⁵The empirical materials that support the analysis were gathered during extensive field work in the Franco-Genevese region during Fall and Winter 2009-2010. It consists of original out-of-print documents and interviews with several political actors involved in the governance of the aquifer.

emphasize that water management regimes inherently reflect new knowledge and are ultimately vulnerable to it. New knowledge and information about the G n vois Aquifer influenced the cognitive frameworks in which political actors formulated their policy preferences and shaped the bargaining process leading to the co-management of the shared resources.

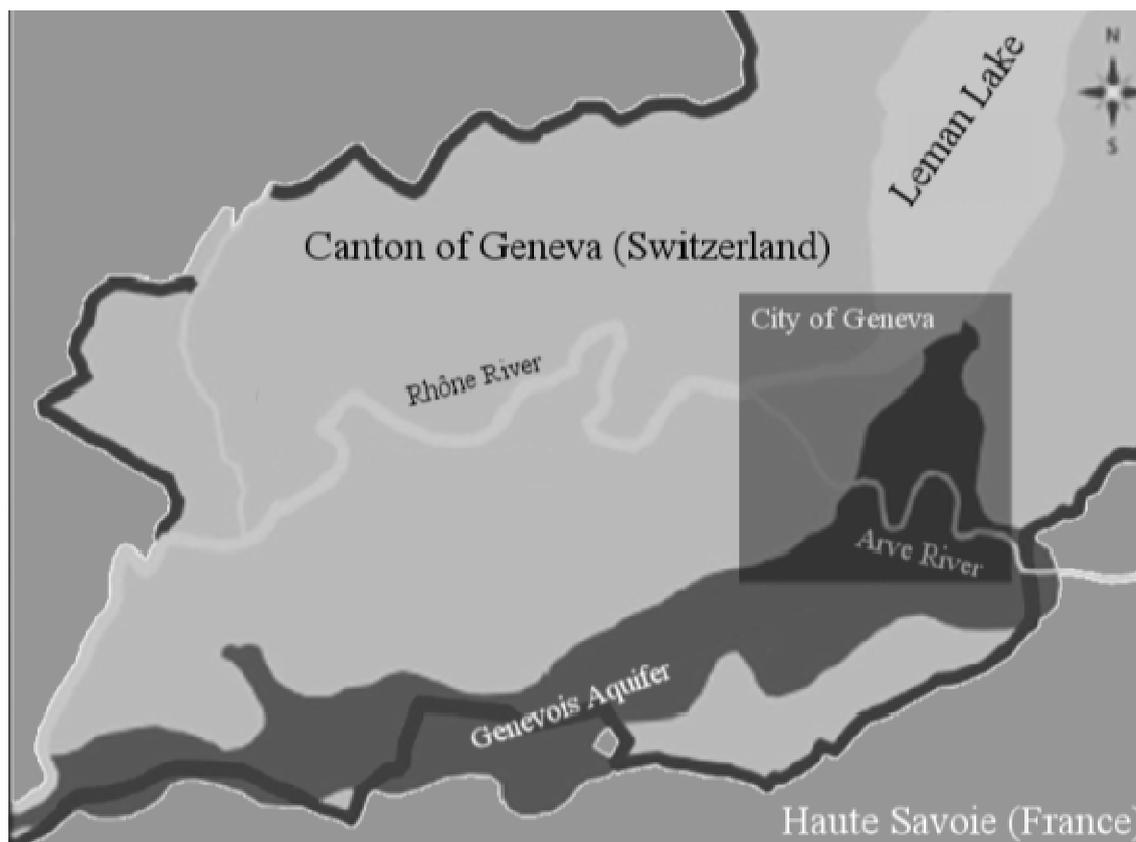


Figure 4: The G n vois Aquifer

Source: Adapted from etat.geneve.ch/dt/geologie/eaux_souterraines-270.html (retrieved January 2010)

B - Hydropolitics in the G n vois Region

Interventions for the progressive control of the major alpine rivers and lacustrian systems in the Franco-Genevise region began in the nineteenth century and continued through the twentieth century. These operations played a critical role in the development of the region, which

grew concomitant with the increased control of the natural resources. The control of the regional waters helped tackle historical problems such as recurrent seasonal floods or insufficient water supply in some parts of the region. Arguably for the first time, the extensive control of the water resources became an attainable political goal, and water management initiatives echoed the availability of new institutional and technical tools for the control of the territory (Chappuis 1886, Vischer 2003). Through extensive operations, the regional waters became at once a source of freshwater for human consumption and a means to both improve urban sanitation and power industry. Water management was not a politically agnostic phenomenon: it reflected ideological struggles, the changing definition of social priorities, and available technical and financial resources. The increased control and exploitation of the regional water resources is inextricable from the growth of the city of Geneva and its politics.

The Genevese expansion of the water supply systems and the infrastructure interventions also created tensions among the users of the water resources. This is because Geneva's water works triggered changes in the water resources, leading, for example, to the recurrent overflowing of the Lemman Lake in 1857 and to two major floods in 1877 and 1879 (Vischer 2003). Riparian communes led by the Canton of Vaud reacted by hiring experts⁵⁶ to devise alternative approaches to water management and challenged Geneva in the Federal court in 1878 (Chappuis 1886). They demanded the establishment of water relief mechanisms to regularize the region's water levels. In November 1884, the Cantons of Vaud and Geneva signed an *Inter-*

⁵⁶ The Canton of Vaud contracted Karl Pestalozzi and Gottlieb Heinrich Legler in 1872. These experts produced a report in 1874 suggesting changes that would enhance the flow of the Rhône River, thus reducing summer floods. Their suggestion to implement a relief mechanism on the Rhône River was implemented as part of the Coulouvrenière facility (Vischer 2003).

cantonal Convention for the Correction and Regularization of the Lemman Lake Flow.⁵⁷ The Convention, approved by the Confederation in 1885, established mechanisms for the control of the Lemman Lake levels: the dredging of the Rhône River, the dismantling of constructions that affected the river's flow, and the construction of new flow-relief mechanisms. The agreement offered a new opportunity to simultaneously replace failing water supply equipment and expand control over the water resources. In order to implement the inter-cantonal agreement, Geneva created a new intervention on the Rhône River between the Lemman Lake and the Junction Bridge. The city's water utility began the construction of a new water pumping installation, the *Bâtiment de Forces Motrices de la Coulouvrenière*, in 1883.⁵⁸ Partially operational by May 1886 and fully functional by 1892, the new facility was able to supply the city as well as neighboring communes located up to 10 kilometers away. The new station also powered the flourishing city's industry, regularized Lemman Lake levels, and provided the long sought flood control mechanism (Vischer 2003, Zanasco 2006).⁵⁹ Significantly, the inter-cantonal agreement served as a framework for the resolution of water management problems exceeding the canton's jurisdiction.

successive water management operations—the sophistication of the water supply and the flood protection mechanisms—solidified Geneva as both the major economic and political center in the region and the most important regional center for scientific research associated with water management. Water works facilitated the integration of scientific and technical expertise into the policy-making process and the development of institutional and legal instruments dedicated to water issues. The advent and popularization of modern science and technology were inextricable

⁵⁷ The agreement was later co-signed by the Canton of Valais.

⁵⁸ The original facility still stands and was reconverted into a museum and theater during the 1990s.

⁵⁹ In 1897, 13 new water-pumping turbines were added to the facility. Geneva's water jet originally resulted from the occasional release of excess pressure in the water supply system (Giacasso 1987).

from the liberalization and radicalization of academic and political institutions (Rossier 1953). Sciences progressively gained legitimacy within academic institutions and in political decision-making. As part of this process, scientists actively participated in the public arena as they fought for the recognition of their respective disciplines in the academic realm. Many were involved in business and projects for public infrastructure: they designed and built the hydraulic machines, dams and new machines for industry that were required and fuelled by the economic development of the region. The scientific knowledge and new technologies that they developed helped control and exploit the region's waters, which was critical for the development and modernization of Geneva (Paquier 2007, Paquier and Pflieger 2008). In the process, technical expertise gained political legitimacy in decision-making about water management interventions.

1) Groundwaters in the Water Supply

The management of natural resources contributed to the continued demographic and economic growth of the region. Growth, however, was accompanied by increased water demand, and the supply of the communities located far from the city of Geneva's main water supply systems became increasingly expensive and complicated. Historically, the communities located far from surface water resources had resorted to small surface streams and shallow groundwater wells for their water supply. As these resources became insufficient to cope with demand and other water resources remained inaccessible, waters from the regional aquifers became increasingly important for the regional water supply (Pazziani 1954).

The first users of the G n vois Aquifer knew relatively little about its extension and hydrogeologic properties. In 1865, a small private company started supplying the communes located east of Geneva with freshwater. The Canton granted a certain M. Schmidt a concession

to build a dam on the Arve River and use hydraulic motors for the supply of the inhabitants located nearby. In 1866, the State authorized the transfer of M. Schmidt's concession to a newly founded company, the *Société des Eaux de l'Arve* (SEA) (*Journal de Genève*, August 26th 1950, 6). The waters delivered by the new company were not those of the Arve River, but instead were abstracted from wells located on the river's margin. Groundwater was preferred because the terrain naturally filtered the river waters, making them potable at no cost. In 1902, the company began abstracting water from new deeper wells (54 meters) in the same location and would continue to do so throughout the twentieth century. By 1970, the company supplied the communes of Veyrier, Trois-Chênes, Vandoeuvres, Choulex, Collonge-Bellerive, and Champel, totaling around 60,000 inhabitants (Stolz 1999).

In the west and southwest areas of the Canton of Geneva water supply was problematic. These communes were located too far away from the city center to be supplied from the city's water-pumping stations or from the SEA's network. As these communities began struggling to cope with demand, Geneva's water services—a component of the larger public utilities conglomerate, the *Services Industriels de Genève*⁶⁰ (SIG)—began exploring alternative means to supply them. The public utility was particularly interested in exploiting the aquifer that was being utilized by SEA (*Journal de Genève*, February 20th 1930:14) and decided to hire a local scientist to explore the possibility. The consultant, Etienne Joukowsky, conducted extensive investigations in the region and suggested locations for the installation of new wells (Joukowsky 1942, Anonymous 1948). Geneva's water utility installed groundwater pumping stations in Soral

⁶⁰ The Industrial Services of Geneva are responsible for the supply of water, gas and electricity in the Canton.

in 1932, Saconnex d'Arve in 1935, and Fontenex in 1941 (Calame 1943, Pazziani 1954). SIG began intensively exploiting the aquifer alongside SEA by the nineteen-forties.

The French communes located between Gaillard and Annemasse, St. Julien-en-Génévois, and Viry along the Franco-Swiss border began exploiting the aquifer in the late nineteen-fifties. Groundwater quickly became a critical component of the supply of the fast-growing communes as they transformed into suburban extensions of the city of Geneva. These communes also exploited shallow aquifers and small surface streams, but the quality of these waters deteriorated quickly as the communes urbanized. Alternative sources of water became too limited or too polluted to respond to demand and groundwater became the principal source of water (Bonnard and Gardel Ingénieurs-conseils 2006).

2) The Scientific Assessment of the Aquifer

The expanded use of regional groundwater resources was supported by scientific research that developed during the nineteenth century. The first geologic characterization of the water-bearing formations in the Franco-Genevese area was authored by Alphonse Favre in the late eighteen-sixties. It was part of a larger geological description of the Canton of Geneva in which the geologist depicted the quaternary formations that underlie the canton (Favre 1867, 1873). Although his research focused on the general tectonic features of the region, his work laid the foundations of future research on the region's hydrogeology (Amberger, *et al.* 1988). Further investigations by other scientists filled gaps in the hydrogeological characterization of the region. By the 1940s, regional geologists and hydrogeologists had accumulated significant knowledge about the region's hydrogeology (Joukowsky 1941), and it was publicly known that the

groundwater resources being exploited across the Canton of Geneva and in the French border communities belonged to a single aquifer (*Journal de Genève*, May 5th 1942: 4).

Geneva's Cantonal Service of Geology was founded in 1964 for the monitoring and assessment of regional hydro-geologic resources. Staffed with scientific experts, the Service surveyed regional groundwater demand and the effects of exploitation on the aquifers, gathering information from the different users and constructing a database that evidenced the effects of the anarchic abstraction of groundwaters on the regional aquifers. Furthermore, through the centralization of scattered information about the aquifers, the Service highlighted the users' interdependence on the shared resources, as well as existence of common problems. In the process, the work of the Service also led to changes in the denomination of the regional aquifers and the formulation of the G n vois Aquifer. During an interview, Gabriel de los Cobos, the civil servant in charge of overseeing the technical aspects of the management of the Aquifer at Geneva's GESDEC ("*Service de G ologie, Sols et D chets*"), explained: "*We used « Arve aquifer » because the aquifer is strongly influenced by the [Arve] River, and because historically its waters were drawn exclusively by the Soci t  des Eaux de l'Arve. It is still part of common-speak because the Industrial Services of Geneva had a part of their water supply network based on the Arve Aquifer too. We preferred using the name "G n vois Aquifer" because it is more telling of the aquifer's transboundary nature. The 'G n vois' is a global name for the Franco-Swiss region. (...) we considered the name was more adapted than 'Arve Aquifer' because some people will still tell you that the aquifers located far from the river have different waters. (...) Here, it is often hard because people have trouble understanding the connection with the Arve River... Some still doubt the connection between them.*" (Gabriel de los Cobos, Interview, January 2009)

The G n vois Aquifer was historically known as the Arve River Aquifer, due to the location of the first water pumps and the name of its historically largest user. The new denomination not only reflected the better knowledge of the regional resources, but also highlighted that users located in different parts of the region were drawing water from the same aquifer. Although the aquifer's original nomenclature long persisted in many publications and technical reports, the new name helped reinforce the idea of a common transboundary resource.

The volumes of groundwater extracted from the G n vois Aquifer increased with the construction of new wells across the Canton of Geneva and in Haute Savoie. Water abstraction from the aquifer increased progressively but at a relatively slow pace until the nineteen-forties. The majority of the extraction was performed by SEA until the installation of new wells by SIG, which triggered an important increase in the extraction rates. Until 1957, the two water utilities in the Canton of Geneva were the sole users of the aquifer, at rates of approximately 8 million cubic meters a year. The volumes of groundwater being extracted were still below the natural recharge threshold. Then the development of new water pumping stations in France during the nineteen-fifties tipped the balance: average water levels within the aquifer started dropping quickly by the end of the decade. The average levels within the aquifer, which had historically hovered around 377 meters,⁶¹ began decreasing by almost two meters per year. The increases in demand were largely driven by the regional demographic and economic growth: SEA, for example, had to double its extraction rates in 1962, to 26,000 liters per minute to cope with new users (*Journal de Gen ve*, January 7th 1963: 7). By 1970, the volume of water extracted from the aquifer reached around 12 and 14 million cubic meters per year, which was between 3 and 5 million cubic meters per year more than average natural recharge, which was established at 9

⁶¹ Average aquifer levels are measured using sea level as zero.

million cubic meters per year (Baroni 1979).⁶² Monitoring systems, installed as the new wells became operational, demonstrated the correlation between groundwater extraction and the aquifer's levels (Baroni 1979, Amberger, Siegenthaler et al. 1981).

In view of the aquifer's deterioration and having connected groundwater-dependent regions to the general water supply network, SIG voluntarily decided to progressively reduce its reliance on groundwaters in the early nineteen-sixties (Pazziani 1954). The initiative only slowed the deterioration of the aquifer, as the other users continued increasing water abstractions. As new French pumps became operational in the early nineteen-sixties, water levels dropped even faster. The G n vois Aquifer was being exploited by wells constructed and managed by Geneva's two water utilities, the Services Industriels de Gen ve and the Soci t  des Eaux de l'Arve, as well as the French communes of Annemasse, Gaillard and St. Julien-en-G n vois.⁶³

Data on the aquifer's deterioration was starkly highlighted with the results of a survey conducted during the nineteen-seventies about future regional groundwater needs (Baroni 1979). Results suggested the water supply would be insufficient to cope with regional demand unless groundwater levels were maintained above minimum levels. Were the aquifer's levels to fall below particular thresholds,⁶⁴ groundwater pumping would no longer be possible and the water supply would be insufficient, which posed a significant threat to the operations of users on both sides of the border.

⁶² In addition to growing pressures from demand, drought limited the natural volumes of recharge, which further affected the aquifer's levels.

⁶³ In France, the water wells were managed by two multi-purpose inter-communal syndicates—public utilities serving more than one commune—in the cases of Annemasse and St. Julien, and the commune of Gaillard.

⁶⁴ Minimum levels varied for different pumping stations.

C - Problems and Management Options for the G n vois Aquifer

The over-exploitation of the aquifer created a specific set of problems. The general availability of water *per se* was not one of them, since waters could theoretically be drawn from Lemman Lake and other regional surface water sources. They were instead associated with the costs of switching water supply systems from groundwater to surface resources and the security of the water supply, two factors that could hinder the development of the communities relying on the G n vois's groundwaters. Drying wells needed to be replaced with new infrastructure and implied the loss of investments associated with their exploitation. The depletion of the aquifer also meant that groundwater would no longer constitute an alternative source of freshwater. Without groundwater, the region would be entirely dependent on the availability of surface water. Multiple sources of water reduced the vulnerability of the water supply. This matter was all the more relevant at the time because it coincided with the first signs of qualitative deterioration of the Lemman Lake (Jouve 1995). As the problems associated with groundwater became more apparent, scientific investigations focused on the identification of the zones of recharge, hydraulic linkages and the specific hydrogeologic features of the terrain. This information helped specify the aquifer's features and confirmed that all the users were effectively drawing water from the same source. Furthermore, it helped identify the factors causing the drop of the water level and explained the effects of these changes. In the end, this information fostered the parties' agreement on both the nature of the problem and its causes.

There were two alternatives for solving the problems of the G n vois Aquifer. One of the solutions was to extract more waters from regional surface waters. This alternative required, besides the construction of new water-taking facilities, the integration of the regional water supply infrastructure. Although it was not a technologically complicated solution, it was costly.

A new water treatment facility for extractions from Lemman Lake was estimated at 250 million Swiss Francs (Baroni 1970, de los Cobos 2002), not including the investments necessary for the transportation of the waters across the region. Further reliance on surface waters also meant that existing groundwater exploitation infrastructures, which were significant capital investments, would be abandoned. Moreover, this approach would also limit Geneva's diversity of supply sources, which meant that if the surface water resources became polluted, the city would be left without any alternative sources of freshwater (de los Cobos 2002). The alternative option, suggested by the Director of Geneva's *Service Géologique*⁶⁵, was the artificial recharge of the Gènevois Aquifer. The injection of surface waters into the aquifer could potentially restore water levels and compensate for over-draft practices. The appeal of such an approach was rooted in its maintenance of the status quo: users would not be required to drastically modify their practices. In addition, the restoration of the aquifer's levels would protect existing investments, allowing water-taking infrastructure to remain operational, as well as provide an alternative source of freshwater in the Canton, which was useful in case of environmental emergencies affecting the surface waters.

Unlike the surface water option, the artificial recharge of aquifers presented significant technical, economic and political challenges. The technical conundrums were associated with both the aquifer's features and the means preferable to effectively recharge it. The solution needed to be able to restore water levels across the entire aquifer, and this depended on the aquifer's geomorphology and transmissivity rates. For example, if due to the properties of the

⁶⁵ The Service of Geology was in charge of the original studies on the aquifer. The first Director of the Service was Gad-François Amberger, assisted by Daniel Baroni. Both civil servants were prominent scientists in the field of geology and hydrogeology.

aquifer, injected waters were unable to reach intended destinations in time, the artificial recharge would not be very useful; waters needed to spread across the water-bearing formation at rates that offset the user's abstraction. Also, the artificial injection facility needed to be cost-effective and politically workable. If either financial means or political support were lacking, it could not come to fruition, as it would necessarily demand the construction of new infrastructure and cooperation between the users.

The artificial recharge of the G n vois Aquifer was not an entirely original idea. Many other aquifers had already been restored using this method. It had been used since the nineteenth century in Glasgow (1810), Toulouse (1821) and Lyon (1854), and implemented in Germany, Sweden, Hungary, and several U.S. states during the first half of the twentieth century (Baroni 1970). Probably more significantly, two Swiss aquifers were already being recharged in Basel and Neufchatel by the end of the nineteen-sixties: these experiences demonstrated that the deterioration of aquifers was potentially reversible (Baroni 1970). However, whether the artificial recharge of the G n vois Aquifer was feasible would depend on its particular hydrogeological features.

In order to explore the feasibility of such a solution, Geneva's Service of Geology, in association with SIG's Water Service, conducted a series of tests between 1967 and 1974. These tests filled knowledge gaps and assessed the consequences of injecting surface waters into the G n vois Aquifer. They evaluated the speed at which waters, which were radioactively marked and monitored, infiltrated and spread within the aquifer. In fact, the first experiments involved the irrigation of a non-confined area of the aquifer with surface waters of different quality.

Gabriel de los Cobos detailed the process in layman's terms: *“They looked at the possibility of what was called the artificial enrichment of the G n vois Aquifer. They tested it with the lake’s water but results were negative because they were quite a few biological problems. It is not the same water. They then thought to use the waters that naturally infiltrate the aquifer, the Arve River. After a series of tests, and stages... because it was necessary to find the right location for the re-infiltration... several infiltration methods were tested: infiltration basins and wells. (...) They decided to infiltrate directly through the alluviums. It is important to note they were quite lucky on the location where they did the tests.... The location had great geologic qualities and is now considered one of the best places to do it. This is because the Arve alluviums are deposited directly over those that make the aquifer. The infiltration of those alluviums permitted the immediate recharge of the aquifer. They also installed filtration mechanisms to enhance the quality of the water. ”* (Gabriel de los Cobos, Interview, January 2010).

By 1971, the success of the initial recharge experiments led to the installation of a field laboratory dedicated to furthering the investigations. It was located close to the SEA’s Arve River facility in Vessy. The new tests focused on the physicochemical properties of the groundwaters and the Arve River (Baroni 1979). They confirmed that the aquifer’s natural recharge stemmed largely from the Arve River, as the aquifer’s levels changed concomitant with the river’s hydraulic regime and the waters’ shared chemical properties.⁶⁶ The laboratory monitored the aquifer levels’ seasonal fluctuations and the presence of pollutants in the

⁶⁶ Originally, scientists believed that the aquifer received recharge from the Lemman Lake. Infiltration tests and the chemical comparison of the waters demonstrated the aquifer received little recharge from the lake. The waters had different temperatures and chemical composition.

groundwaters. Moreover, it was a testing ground for different methods of water injection: it evaluated alternative water-filtering techniques, as well as the effects of alternative approaches to the imperviousness of the terrain and the quality of the groundwater.⁶⁷ Investigations suggested that surface waters would require minimal treatment previous to their injection, limited to sand removal, flocculation and filtration. The tests concluded that the recharge of the aquifer was feasible.

In terms of its economic costs, the artificial recharge of the aquifer was more appealing than switching to a supply exclusively based on surface waters. Besides protecting existing investments in infrastructure and avoiding the construction of elaborate water transport systems, the cost of an artificial recharge facility was calculated at about 17 million Swiss Francs (Baroni 1979, de los Cobos 2009). This was significantly less than the 250 million Francs estimated for the construction of a new surface water taking and treatment plant to further exploit the Lemman Lake. Given the economic cost and the technical viability of the recharge solution, the major factor potentially precluding the installation of the artificial recharge facility was political. The construction and long-term operation of the water injection facility required an important economic investment. Consequently, the initiative was thus ultimately dependent on the willingness of the users to finance its construction and to undertake the necessary regulations to control the exploitation of the aquifer.

⁶⁷ The Arve River is fed by the Glaciers of the Mont Blanc. During summer, which is the season of high runoff, the waters carry sediments that make them turbid. The solids in the water could potentially modify the imperviousness of the areas of recharge and the pre-injection filters, thus making recharge operations ineffective.

1) The Asymmetric Impact of the Aquifer's deterioration

De los Cobos argues that “the political will to develop a cross-border project emerged naturally in parallel with the studies and tests that were carried out on the experimental plant” (de los Cobos 2010, 12). He suggests that the political will to support the artificial recharge was rooted in the bilateral interest to protect the resource. From his perspective, shared interests “emerged naturally” from the increased understanding of the G n vois Aquifer properties and the assessment of alternative courses of action by its users. It reflected a process in which users progressively constructed their respective preferences.

In the mid-nineteen-seventies, the Canton of Geneva contacted the bordering French communes to inquire about their interest in participating in the management of the aquifer (*Journal de Gen ve*, April 13th 1976: 5). The French communes were asked to partially fund the construction and the operation of an artificial recharge facility and to regulate their consumption of groundwater. The users of the aquifer held several meetings in which they discussed alternative means to deal with groundwater problems. They debated the reduction of water abstraction rates and cost-sharing mechanisms for the construction of the facility. Simultaneously, they discussed their respective reliance on different water resources, as well as the hydrogeological features of the region, and evaluated the costs associated with different sources for water supply. These assessments led some users to reduce their reliance on groundwaters. However, users relying exclusively on the groundwaters, including some but not all users in Haute-Savoie and SEA in Geneva, were unable and unwilling to follow suit. Inability resulted from both the lack of alternative sources of freshwater and the costs associated with supplying alternative sources of water; unwillingness reflected the strategic opportunity to free-

ride unilateral actions taken by other users to restore the aquifer. This was because the aquifer's deterioration did not affect all users of the aquifer equally.

In the Canton of Geneva, the principal user of the aquifer, SEA, relied exclusively on the groundwater resources: the firm would not survive a transition to surface waters. SIG, the other major user of the G n vois Aquifer in Switzerland, had voluntarily begun reducing its reliance on the resources as early as 1965. In France, users faced different situations depending on their respective geographical location: *“There were three or four different zones on the French side. This section, between Gaillard and Annemasse.... They had several wells and were interested but were seeking for water in the Arthaz Aquifer. They apparently had an alternative. [The commune of] Saint-Julien had wells here, and was considering the construction of further water wells. They were interested in maintaining water levels in the aquifer. And then, the commune of Viry didn't really have a choice: they needed minimum levels to abstract groundwater.”* (Gabriel de los Cobos, Interview, January 2010)

The interest of the different communes in the restoration of the aquifer was shaped both by their respective reliance on its resources and their capacity to switch to alternative sources of water. Each commune had different stakes in the resolution of the groundwater problems. For some, groundwater deterioration posed threats analogous to those faced by the Swiss public utility: they were mainly associated with the financial cost of transitioning to alternative sources of freshwater. For others, however, such as the communes Saint-Julien-en-G n vois and Viry, the depletion of the aquifer directly threatened the freshwater supply, because these communes had limited access to other sources of water. Worse, being located on the margins of the aquifer,

these users would not be able to free-ride a potential Swiss restoration of the aquifer. Geneva could potentially recharge the aquifer at levels that would keep their wells dry.⁶⁸

2) The Alignment of Management Preferences

As dependency on the groundwater resources became apparent, interest in the restoration of the water levels in the aquifer aligned. Initially at odds, the preferences of the French and the Genevise users eventually pointed to the cost-effectiveness of the joint management of the resources. The Swiss would have likely proceeded with the recharge of the aquifer independently of French preferences. In fact, the Canton of Geneva passed a law on June 24, 1976 permitting the appropriation of the funds necessary for the construction of the recharge facility. It authorized a 15.5 million Swiss Franc loan and a special new tax on all groundwater abstraction.⁶⁹ Geneva's Council determined that the facility would be installed on the testing grounds used to study the aquifer's reaction to artificial recharge, which it had acquired in 1970 (*Journal de Genève*, February 14th 1976:9). It would be located upstream of SEA's Arve River dam in order to benefit from the higher Arve River levels during the dry season.

In France, *“there were multiple turnarounds. People would agree, and then show disinterest. In fact, the French had expectations for their aquifers... they found water, but the volumes found were not as large as they expected them to be. They then expressed interest [in the restoration of the aquifer] but not in directly financing [a joint management initiative]”* (Gabriel de los Cobos, Interview, January 2010). The French communes were initially reluctant to

⁶⁸ The margins of the aquifer are thinner and thus more sensitive to changes in the water levels, which made wells located there more vulnerable to groundwater depletion.

⁶⁹ The tax charged \$0.13/m³ of groundwater pumped and was adjusted according to the effective costs of recharging the aquifer (Baroni 1979).

participate in a negotiation over the management of the shared resources. However, given increasing information about the relative costs of exploiting alternative sources of water, they eventually accepted participation in negotiations. They did so because they were aware of the costs of transitioning to a water supply based on alternative sources of freshwater and especially because free-riding the Swiss intervention would not be possible for all French communes. In France, this information was used by the more vulnerable communes to pressure those less reliant on the aquifer to participate in talks with Geneva.

Although at first the situation seemed to fit well with the tragic fate of common pool resources described by Hardin (1968), the strategic mobilization of knowledge about the resources and alternative management approaches reshaped the incentives of the users of the G nevois Aquifer to cooperate. As knowledge about the hydrologic conditions advanced, it became increasingly clear that cooperation was strategically preferable to the depletion of the aquifer.

D - The Joint-Management of the Groundwaters

The formalization of a formula for the joint management of the transboundary aquifer was riddled with legal and administrative difficulties. The Canton of Geneva possessed the political and administrative authority to create and implement international cooperative agreements, but the French border communities lacked the necessary authority to autonomously engage in bilateral negotiations. In fact, as stated by an expert in Franco-Genevese transboundary relations, the signature of a formal agreement required the participation of French political authorities, who were at once “unaware and uninterested in the problems of the small transboundary aquifer”

(Nicolas Levrat⁷⁰, Interview, January 2010). This was a common problem in Europe during the 1970s. It was connected to the limited capacity of the regions to autonomously resolve international, albeit locally relevant, problems in a context of increasing regional integration. In this case, it was compounded by the absence of legal instruments specific to the management of international aquifers from which to draw principles or guidelines. At the time in which Franco-Genevise authorities were considering the best means to deal with the problems of the G n vois Aquifer, international debates only summarily included aquifers—as part of larger discussions about international surface waters—and not a single formal international agreement dealt exclusively with them (Wohlwend 2002).

Despite the challenges, the State Council of the Republic and Canton of Geneva and the Prefect of Haute-Savoie formalized a (renewable) 30-year agreement in June 1977 for the management of the G n vois Aquifer. The “*Arrangement relatif   la protection,   l’utilisation et   la r alimentation de la nappe souterraine franco-suisse du G n vois*” entered into force in January 1978 and simplified the coordination for the protection and continued use of the shared aquifer. Through its provisions, Geneva and the French neighboring communes regulated groundwater exploitation, mandated the artificial recharge of the aquifer, and established mechanisms for the systematic exchange of information about the usage of the aquifer. The agreement’s provisions made existing practices sustainable by warranting the maintenance of the *status quo*, rather than drastic political or behavioral change on either side of the border. Existing users were guaranteed access to the groundwaters. In addition, the arrangement created barriers to new water extraction projects. The joint management of the shared resources would permit the

⁷⁰ M. Levrat is the attorney responsible for the legal formulation of the 2008 Convention signed to renew the 1978 arrangement as it expired.

continued exploitation of the aquifer at limited extra cost for the users and dispel future threats posed by changes to groundwater levels. In order to accomplish these goals, the arrangement established a bi-national commission charged with the supervision of the aquifer's exploitation and allocated the aquifer's water.

The binational Commission (articles 1–6) charged with steering the management of the aquifer was composed of three representatives from each country, two of whom had to be technical experts in water management. They would meet at least twice a year to assess the aquifer's condition and supervise groundwater use. The first task of the Commission was to enforce a ban on groundwater abstractions for the years in which the average aquifer level dropped below 368 meters (above sea level). Then the Commission would prepare a yearly management program based on the performance of the recharge facility, users' projected requirements, and potential threats to the quality of the groundwater. The Commission centralized information and expertise on the exploitation of the aquifer. Its function, however, remained consultative: authorizations, permits and concessions to extract groundwater remained with the respective national authorities. The bilateral review process became a necessary step for the issuance of new municipal permits for the construction of new groundwater pumping facilities or the modification of existing infrastructure. In essence, the technical expertise of the Commission became an important component of decision-making on both sides of the border.

The arrangement allocated the aquifer's waters asymmetrically. The French communes were allocated a maximum of five million cubic meters per year⁷¹ with extractions of more than two million cubic meters charged according to a formula specified in the agreement (article 9).

⁷¹ This figure could, in theory, be reviewed by the Commission in case of necessity.

The two million free quota corresponded to the volumes of groundwater extracted by French users at the time the agreement was signed. The charges for extractions beyond the quota factored in the costs of operating the artificial recharge facility, depreciation, the total volume of water extracted from the aquifer, the volume of natural recharge, and the total volume of groundwater abstracted by the French. Conversely, the water allocated to the Swiss was restricted only by the aquifer's recharge capacity.⁷² In exchange, Geneva assumed the (financial) responsibility for the construction and operation of the recharge facility (Article 8). This approach accommodated existing users of the aquifer and created a clear economic deterrent to increased abstractions from the aquifer. It also defrayed costs associated with its restoration, which was politically instrumental to the French communal authorities. They could reap the political benefits stemming from the rapid restoration of the aquifer and defer the economic costs of groundwater regulation. In other words, the French would effectively free-ride the recharge of the aquifer, as long as demand remained constant, or slowly adjust to the progressively increasing costs of exploiting groundwater. Conversely, the Swiss obtained guarantees that the French would regulate their groundwater exploitation, as well as potential payment for groundwater use, which was necessary for the effectiveness of the artificial recharge approach.

The arrangement was negotiated by the authorities of the French border communes and signed by the Prefect of Haute-Savoie. From a legal standpoint, neither possessed the formal authority to engage in international negotiations or the development of joint policy for environmental management. Environmental management decisions and international relations were prerogatives of the national-level authorities, not the local representatives. In essence, local

⁷² The aquifer's total estimated maximum recharge (natural and artificial) was estimated at 17 million cubic meters per year.

authorities were—in theory—formally restricted by national administrative law and country-level political concerns from negotiating and signing the 1978 arrangement. The centralized nature of the French political system at that time limited the legal validity of the agreement, and the agreement would have likely been dismissed had any of the parties ever challenged it: “*Many things were going on at the time, although they were extremely informal. The 1978 accord is a typical example of that time. I mean... The actors directly concerned sat around a table, and after realizing that no predefined juridical agreement existed, they agreed as with a contract of private law. (...) They bargained and put down a solution on paper that was generally well respected, but lacked any legal validity. We would have faced problems had it ever been challenged... But that never happened, which is typical of transboundary relations [in Western Europe].*” (Nicolas Levrat, Interview, January 2010)

E - Conclusion : Formally-Coordinated Management

The 1978 agreement was a “pragmatic” instrument of political cooperation (Yamada 2004, Scheumann and Herrfahrdt-Pähle 2008) through which the signatories sidestepped discussions about sovereignty, equitable allocation, and administrative asymmetry (Wohlwend 2002). Although each state maintained its sovereign prerogatives over the aquifer, the agreement framed the transboundary aquifer as a shared resource to be managed for the benefit of all users—irrespective of their geographical localization. The agreement thus eluded the typical complexities of international (surface) water law (Eckstein 1995, Benvenisti 1996). Its scope was narrowed to the financial and technical aspects necessary for the joint management of the G n vois Aquifer. Compliance was independent of the agreement’s formal validity because the signatories had the *de facto* authority and interest necessary to autonomously enforce it. Moreover, the Canton of Geneva had the necessary financial resources and technical expertise to build and operate the recharge facility, while the French communes had the power to regulate groundwater exploitation (and pay for the abstractions over the 2 million cubic meters a year quota). The effectiveness of the agreement was rooted in the interest of the parties to abide by it, not in its legality or in their formal authority to sign it. The recharge of the G n vois Aquifer began in 1980 and led to the rapid restoration of the aquifer’s water levels. In the years that followed, the resolution of the aquifer’s principal problems turned the G n vois Aquifer into a political non-issue. Its management was routinized and contentions over the shared resources largely disappeared from the political agenda. Furthermore, with the increasing decentralization of European policy-making, the approach chosen to manage the aquifer was progressively

legitimized, as administrative reforms in France and various European framework agreements validated the 1978 arrangement.⁷³

The co-management of the G n vois Aquifer is based on the existence and recognition of the problems associated with the aquifer; the alignment of political interests in favor of the cooperative resolution of the problems; and the effectiveness of the measures devised for their resolution. Indeed, before the aquifer's existence was socially acknowledged, water management in the Franco-Genevese region dealt exclusively with surface water resources. In the nineteenth century, as scientific discoveries and technological developments gave way to new means to control and exploit natural resources, regional water infrastructure projects thrived. The successive interventions on the waterscape led to the progressive extension of the water supply

⁷³ In the years that followed the 1978 agreement, European countries undertook multiple reforms aimed at the decentralization of administrative structures (Kissling-N f and Kuks 2004). They were instrumental to goals of regional integration and empowerment of the local authorities (Barraqu  1995). The French politico-administrative system underwent major reforms between 1982 and 1987, when the central government partially transferred power to subsidiary authorities. Today, French water policy simultaneously reflects European directives (to which national legislation must adapt), national-level laws, the decisions of basin-level authorities, and those emanating from the local level. The situation in Switzerland is significantly different, as most public policies have historically been determined by the local and regional authorities. Cantons are responsible for decisions regarding the water supply, sanitation and infrastructure, according to their respective constitutions and political institutions (Mauch, Sangare et al. 2004). Although the revision of certain articles of the Federal Constitution has conferred progressively more power on the Federal agencies, the Swiss cantons remain the principal wielders of political authority. In 2007, as the 1978 arrangement expired, legal frameworks supported regional-level agreements and the subsidiary governance of natural resources. Consequently, and in view of non-controversial nature of the management of the G n vois Aquifer, the renewal of the agreement revolved around legal technicalities, rather than political or operational dysfunctions. The central provisions of the original agreement that specified the mechanisms used to manage the aquifer were maintained. Changes concerned the explicit acknowledgement of the legal instruments that legitimized the arrangement and the direct inclusion of the now formally empowered French communes. The arrangement was renewed for thirty years in December 2007. The renewed agreement – now deemed “Convention” – was signed by the Communes of the “Annemassienne” region, the Commune of the “G n vois” Rural Districts, and the Rural District of Viry and the State Council of the Republic and Canton of Geneva.

and control infrastructures, and to economic and demographic growth. The region's expansion also led to increasing demands for water and to the increasing exploitation of the G n vois Aquifer. As the usage of the resources increased, so did the scientific knowledge associated with them. Regional hydrogeological assessments permitted the social recognition of environmental problems in terms useful to policy-makers, as it pushed groundwater issues on to the political agenda. At the same time, the hydrogeological assessments of the G n vois Aquifer demonstrated the particular interdependence existing among the users of the aquifer. The recognition of the asymmetric impact of the aquifer's deterioration and the lack of economically competitive alternative approaches to resolve the water management problems aligned French interests with those of Geneva and supported the joint management approach. The artificial recharge effectively mitigated the deterioration of the shared aquifer, which reconfirmed the legitimacy of the co-management approach and guaranteed the enforcement of the political arrangement.

In essence, better hydrogeological information and modeling techniques changed the perception of the issues at hand, technical capabilities increased the ability to exploit *and* to manage groundwater resources, and societal pressures (population changes, economic uses, and social values) altered the perceived importance of the regional groundwaters. In the different stages of the policy-making process, knowledge of the G n vois Aquifer operated as both a cognitive framework around which preferences were formulated and a power resource that leveraged the preferences of particular actors in the bargaining process. It empowered new actors in the local political arena and supported the pragmatic self-enforcement of the co-management approach. Explaining the emergence of management mechanisms for the G n vois Aquifer

through the analysis of systemic or socio-institutional factors alone misses the more interesting nature of the political process and the changing relevance of these factors in different phases.

VI - The Hueco and Mesilla Bolson Aquifers

A - Introduction

Located at the center of the U.S.-México border, the region known as *Paso del Norte*⁷⁴ is at the intersection of the states of New Mexico and Texas in the United States and the Mexican state of Chihuahua. It extends from Elephant Butte Reservoir in southern New Mexico to Fort Quitman in far west Texas, and it is home to the sister cities of El Paso, Texas and Ciudad Juárez, Chihuahua.⁷⁵ Its climate is marked by the features of the Chihuahuan Desert biome,⁷⁶ receiving less than 240mm³ of rainfall per year (Gehlbach 1981). Despite its aridity, the region has experienced significant economic and demographic transformations since its humble origins as a stopover for the travelers of the old *Camino Real*, which connected Mexico City to Santa Fe, New Mexico, during the nineteenth century. The region has grown steadily since then and is currently home to more than two million inhabitants, making it one of the most heavily populated sections of the U.S.-México border (Herzog 2000, Cervera Gomez 2007). Regional economic and demographic development has, over the years, increased the pressure on the sources of water available in El Paso del Norte, which are the Rio Grande/Bravo and regional aquifers (see Figure 2).

⁷⁴ “Paso del Norte” translates to the Northern Pass. It referred to the crossing of the Rio Grande/Rio Bravo by the “*Camino Real de Tierra Dentro*” – also known as the *Chihuahua Trail* or *New Mexico’s Royal Road*. The royal road was the sole trading route uniting Mexico City with Santa Fe (Moorhead 1995).

⁷⁵ May of 2011, the city’s name was officially changed to *Heroica Ciudad Juárez* – this in commemoration of the 100th anniversary of the Battle of Juárez (a major event during the early period of the Mexican Revolution). The longer denomination is seldom employed by public officials (Hamlyn, personal communication 07/2012).

⁷⁶ The borderlands are water-scarce lands, described as “dry desert seas and wetter mountain islands.” They are a challenging setting for fauna and flora alike (Gehlbach 1981:265).

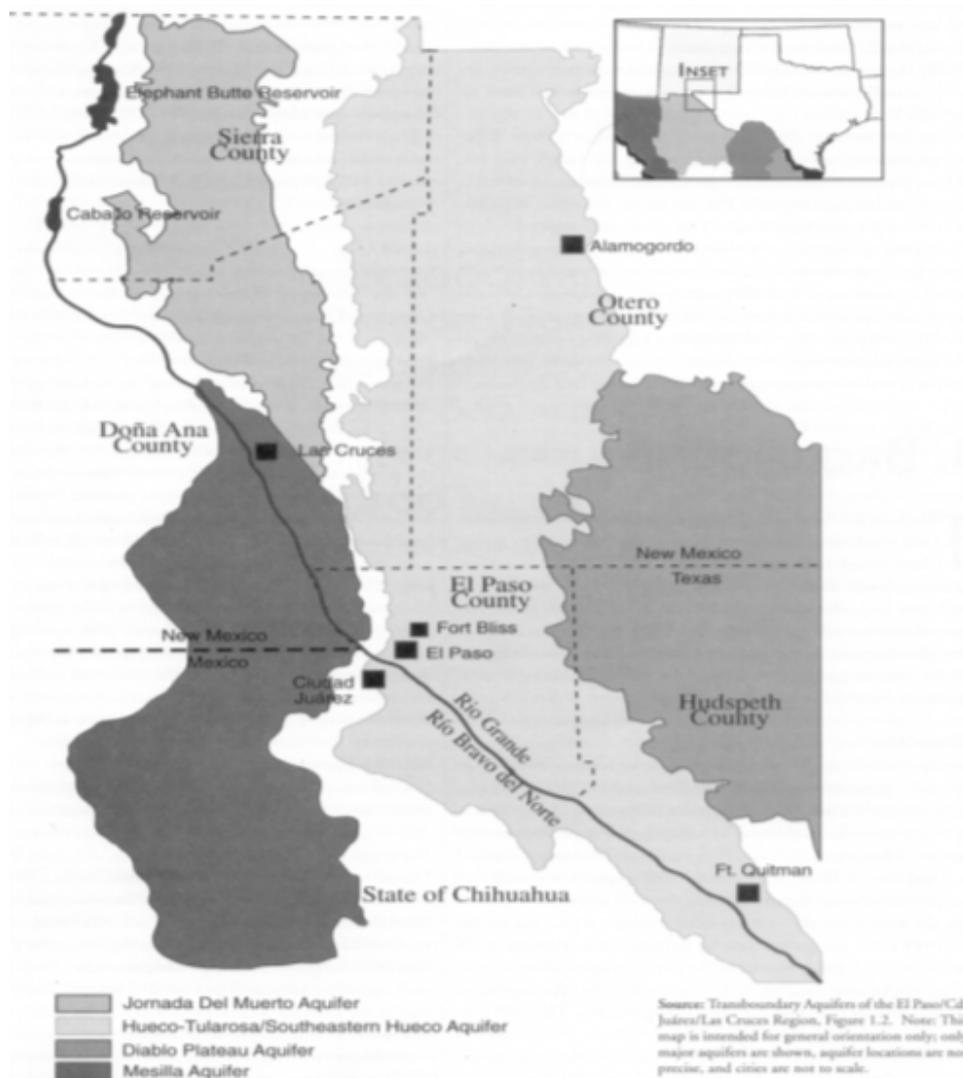


Figure 5: Map of the Paso del Norte Region, the Rio Grande/Bravo River, and the Regional Aquifers

Source: Adapted from Brown et al. (2002)

Subjected to the concurrent effects of arid climate, relative political marginality, and competing demands, water management decisions at El Paso del Norte have historically been accompanied by conflicts—mostly legal disputes, as opposed to military confrontation. Increasing and stabilizing the water supply necessary for the development of the region demanded significant interventions on the natural landscape: the construction of water reservoirs,

dams, canals and other infrastructures dedicated to catching, storing and distributing the waters available in the region. Regional development hinged on and was fostered by an increasingly complex water management regime that established the principles for the allocation of the regional waters and assured—relatively—the regional water supply. Over the course of the twentieth century, the exploitation of the waters of the Rio Grande was subjected to extensive regulation by a myriad of domestic and international arrangements. The United States and México developed an intricate web of multi-level legal frameworks, institutional bodies, and political authorities in charge of controlling most aspects of surface water management. The institutions of water management at El Paso del Norte ossified the power asymmetries between the users of the resources and their competing conceptualizations of the policy problems. Groundwaters, in contrast, have received far less attention from policy-makers than the water of the Rio Grande – in fact, the transboundary aquifers of El Paso del Norte have never been the object of a bilateral management agreement. Nonetheless, the regional groundwaters constitute the sole reliable alternative to the waters of the transboundary river basin, and the quantity and quality of these resources have deteriorated sharply since the nineteen-fifties. Why have these groundwaters not been the object of co-management agreements similar to those applied to the waters of the Rio Grande? And more significantly, what consequences does the paucity of such arrangements have on the resources?

Studies dealing with the issues of groundwater governance at the U.S.-México border have mainly reviewed the role of power and institutions in both the emergence and absence of new regimes for the management of the resource. Stephen Mumme argued, for example, that the factors preventing the emergence of regulatory instruments to deal with groundwater problems are "*rooted mainly in the decentralization of the water law and administration in the U.S. and*

the concomitant political difficulty of regulating private utilization of these supplies in the absence of a serious threat to urban water supply or at least the perception of such." (Mumme 2005, 6). He claimed that the absence of agreements for the management of the transboundary aquifers of El Paso del Norte is due to the structure of the water management institutions in the United States and the historical absence of pressing groundwater problems. Mumme's explanation is consonant with the findings of Ingram, Laney and Gilihan (1995), which present water management decisions at the U.S.-México border as shaped by the institutional, political-economic and cultural context. Focusing on groundwater resources and the structure and nature of institutional frameworks, Scott and Milman (2010) have suggested that the polycentric nature of institutional arrangements at the border creates barriers to the development of formal agreements for the management of transboundary groundwaters. Similarly, others have highlighted the institutional asymmetries that preclude the development of joint approaches for the governance of the resources at the borderlands (Hamlyn 2001, Evans 2005, Scott, Megdal et al. 2008, Douglas, Lyke-Ho-Gland et al. 2009, Megdal and Scott 2011). In general, these studies posit that the legacies of water management politics and institutions today function as structural barriers to the development of new formal agreements to deal with the threats posed by groundwater deterioration. This is not just because the institutional frameworks constitute administratively complex environments, but also because they are inextricable from the power asymmetries of stakeholders and the distrust that these asymmetries have bred among the actors involved in the management of the resources (Earl and Czerniak 1996, Turner, Hamlyn et al. 2003).

This chapter examines the factors that have prevented the development of a joint framework for the management of transboundary groundwaters at El Paso del Norte.⁷⁷ It purposely sidesteps the exclusive analysis either a systemic or socio-institutional perspective to focus instead on the role of ideational factors in the recognition of the problems of the aquifer, and in the implementation of management decisions. The cognitive aspect is an often overlooked facet of groundwater management that is nonetheless constitutive of the approaches chosen to deal with the resources (Blatter and Ingram 2001). Ideational factors include not only the scientific and technical understanding of the resources, but also the mechanisms that shape the *meaning* of information about the resources. The understanding of the factors behind the deterioration⁷⁸ of the resources is necessary for the emergence of governance mechanisms (Salman 1999; Eckstein 2005; Eckstein and Eckstein 2003): scientific knowledge about groundwaters defines, for example, the geographical scope and the temporality of the problems, and the relevant stakeholders in management discussions and the timeframes for action. The apprehension of this knowledge by public and political authorities is mediated by the social valuation of the resources and the cost of prospective management decisions (Rodriguez-Labajos

⁷⁷ The evidence for this section was gathered during extensive field work conducted between December 2009 and April 2010 at the U.S.-México border, Mexico City and Washington D.C.: 1. 23 semi-directed interviews with water managers, scientific experts, and policy makers; 2. Direct participation in multi-stakeholder meetings dealing with groundwater issues at El Paso del Norte (the annual meeting of the Good Neighbor Environmental Board, meetings of the Paso del Norte Water Task Force and the Paso del Norte Watershed Council); and 3. Visits to surface and groundwater management research centers the University of Texas at El Paso, New Mexico State University at Las Cruces and Albuquerque, the University of Arizona at Tucson (SAHRA and the Udall Center), and the Universidad Autónoma de Ciudad Juárez.

⁷⁸ The word “deterioration” is intentionally imprecise. Aquifers located in arid regions are often more vulnerable to depletion than deterioration, as the latter term implies an impairment of quality. Admittedly, diminished water quality in the form of increased salinity is a common concern, but often the proximate cause of such impairment is the intensive exploitation of the resources (in excess of the so-called ‘safe yield’) that induces lateral flow or upwelling of more brackish groundwater.

2011). The social interpretation of changes in the quantity and quality of groundwater resources as problems is determined by the roles of groundwater resources in economic and cultural processes. This chapter argues that while the absence of formal agreements for the governance of groundwater resources may in some circumstances reflect the paucity of knowledge about the resources,⁷⁹ it may, in other circumstances, when sufficient knowledge is available, signal the understanding that the resolution of the problems is possible without such formal agreements.

The management of surface water resources at El Paso del Norte is rooted in instances of cooperation, which have historically included both bilateral formal mechanisms and informal dialogues. Conversely, the governance of transboundary groundwaters is managed unilaterally, supported solely by scattered information exchanges and guarded dialogues among regional stakeholders regarding issues of mutual concern. This is because the challenges of groundwater governance are distinct from those associated with the competitive exploitation of the waters of the Rio Grande. Unlike surface waters, users may not impede the access of competing users to the resources. However, the assessment of transboundary groundwaters and the implementation of sound strategies for their management problems require information about the resources that can only be produced through bilateral cooperation. In this case, the recognition of the technical components of groundwater problems is concomitant with that of the politico-institutional challenges inherent to the regulation of the resources. Given the institutions and politics of El Paso del Norte, the implementation of formal mechanisms for the management of the shared

⁷⁹ The Supreme Court of Texas famously declared in 1904 that “*Because the existence, origin, movement and course of [ground waters] and causes which govern and direct their movements, are so secret, occult and concealed, an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would, therefore, be practically impossible.*” *Houston & T.C. Ry. Co. v. East*, 81 S.W. 279 (Tex. Sup.Ct. 1904 taken from Hamlyn 2009 ppt, also quoted in Eckstein 2006). (See Also Benson 2011)

groundwater resources is seen as impractical for the resolution of groundwater problems and is actively resisted by local stakeholders on both sides of the border. Still, the absence of formal co-management mechanisms has not precluded the emergence of local-level cooperation processes: on the contrary, it has fostered informal bilateral exchanges aimed at the understanding of the resources and the development of coordinated strategies to deal with groundwater problems.

The chapter is structured in three sections. The first deals with the institutions of surface water management at El Paso del Norte. It reviews the emergence of rules and mechanisms dedicated to the management of the Rio Grande Basin. This is useful not only for navigating the multifaceted paths of environmental change in the borderlands, but also for examining the rationales that underlie water management preferences in the region. The history of the controversies associated with the management of the Rio Grande illuminate many of the politico-institutional conditions for the development of groundwater management mechanisms. The second section describes the emergence of groundwater problems in El Paso del Norte and their entry into the regional political agenda. It reviews the economic and demographic growth of El Paso del Norte and the expansion of knowledge about groundwater resources. It presents the factors that shaped the interpretation of groundwater deterioration as a threat to the regional water supply and to the institutions of water management in Texas. The third and final section of this chapter examines water management decisions at El Paso del Norte since the identification of the groundwater problems and the actions pursued to deal with the groundwater resources. It introduces the unilateral actions undertaken by the water utilities of El Paso and Ciudad Juárez, as well as the semi-formal mechanisms created for coordinated water planning decisions.

B - Hydropolitics at the Paso del Norte

The U.S.-México borderlands underwent a dramatic demographic, cultural, and ecological transformation between the mid-nineteenth and early twentieth century. A new rational order was imposed on the region's landscape by Euro-American settlers (Opie 2006). The conquest of the continent was accompanied by the introduction of new technologies: barbed wire to control cattle; water pumps, dams, and water reservoirs to irrigate the land; railroads to reduce the distances and exchange goods; and machinery to increase the land's productivity (Kroeber 1983, Opie 2000, Hundley 2001). New regulations and infrastructure reshaped regional hydrologic regimes, economies, and demography. In general, the process reflected two powerful ideological paradigms: the idea that controlling natural uncertainties is possible, which was a central theme of the turn-of-the-nineteenth-century positivist rationale,⁸⁰ and the notion that control of the territory is necessary for the assertion of the sovereignty of the State. Seen as both possible and necessary, water management projects were initially relatively few in number and limited in scale. Over the years, however, the scale of intervention grew, as did the political contentiousness associated with the control and use of water resources. Negotiations over the tools and means to control waters reflected increases in demand as well as the proliferation of new problems associated with them.

1) The 1904 compromise

For the communities of the U.S-México borderlands, the management of water resources was a condition for economic and demographic development. El Paso del Norte was settled

⁸⁰ This "modern" positivist paradigm assumes the primacy of developmental goals over environmental conservation considerations based on the idea that technology and progress would help bend the limits indefinitely. During the nineteenth century, promoted by land developers and pseudo-scientists of the time, it was thought crops would foster the increase of rainfall: "rain will follow the plow" (Opie 2000).

largely thanks to the waters of the Rio Grande. By the early nineteenth century, the local population was exploiting the river for thirst-quenching and small-scale farming activities, mostly through ditch-irrigation agriculture and cattle herding (Kroeber 1983).⁸¹ Yet until the late eighteenth hundreds the region remained a scantily populated stopover for travelers (Turner, Hamlyn et al. 2003). The situation began changing rapidly with the construction of a large *hacienda* in what is now downtown El Paso and, especially, with the completion of the Southern Pacific railroad in 1881 (Mills 1921). These developments spurred significant regional demographic and economic growth, and with it, increasing demand for water resources. This growing need for water contrasted with the progressively dwindling amount of water reaching El Paso del Norte towards the end of the century (Kroeber 1983, 149). The concomitant intensification of water exploitation in the upper sections of the Rio Grande basin—in the states of New Mexico and Colorado—was leading to recurrent water scarcity downstream. By the eighteen-seventies, the non-flood flows reaching the downstream sections of the Rio Grande Basin were limited, and the river waters would fail to even reach the borderlands during drought years. In face of these challenges raised by the recurrent and increasingly acute water scarcity, the political authorities of El Paso del Norte explored different means to secure the water necessary for irrigation. They sought political agreements for the allocation of the shared waters and the construction of new water infrastructure.

The emergence of regulatory frameworks and management tools at El Paso del Norte was marked by successive political conflicts. The first controversies over the management of the Rio

⁸¹ Most of the water was actually exploited on the Mexican side of the border by means of a large canalization system, the *Acequia Madre*, which extended from where the Rio Grande enters the El Paso del Norte Valley south into México (Kroeber 1983, 149).

Grande waters pitted the residents of El Paso and Ciudad Juárez against those of southern New Mexico. Irrigators in southern New Mexico's Mesilla Valley and those located in the vicinity of the sister towns had developed competing water management plans, which both aimed to stabilize and secure the water supply and spur regional demographic growth. The Mesilla Valley supported the proposal of a certain Nathan Boyd, owner of the *Rio Grande Dam and Irrigation Company*, advocating for the construction of a reservoir at Elephant Butte in New Mexico (Bath and Petit 1998, Littlefield 1999). Residents located downstream in the vicinity of the towns of El Paso and Juárez favored instead the construction of an international dam a few miles upstream from the border towns (Mills 1921). The projects were incompatible with each other because the construction of the Elephant Butte project in New Mexico would inevitably restrict the volume of excess runoff reaching the border, thus making the downstream dam inoperable. Supporters of the Elephant Butte reservoir challenged the downstream plan by arguing that the construction of the international dam would flood large areas of southern New Mexico. They pointed to the inherent inefficiency of the international dam: not only were waters inevitably lost to evaporation on their way south, but the borderlands were also significantly less fertile than those located upstream (Kroeber 1983, 151).

In 1904, following more than a decade of legal gridlock and formal protestations from the Mexican government⁸² (Clark 1975, Bath and Petit 1998), a recently-minted American water

⁸² The federal government in México issued a formal protestation to the U.S. State Department: *Foreign Minister Matias Romero protested to Secretary of State Olney that such a dam would violate traditional rights of Mexican farmers to have access to river water. (...) Secretary Olney asked for an opinion from Attorney General Judson Harmon. Harmon denied all of Mexico's claims, saying it had no right whatsoever to any river water and there were no restrictions on river water use by U.S. citizens. (...) The United States had complete sovereignty to use the Rio Grande in any way it wanted. Thus, under the so-called Harmon Doctrine, the downstream user had no rights at all. It was readily apparent to many that this meant downstream users such as El Paso, Texas, also had no rights.*“ (Bath and Petit 1998:12)

management body, the United States Reclamation Service,⁸³ announced a plan that would put an end to the conflict. The agency suggested the construction of the water reservoir at Elephant Butte by the U.S. government, rather than Boyd's company. The reservoir would supply water to New Mexico and Texas through a new distribution system, the *Rio Grande Project*, according to irrigation requirements. The plan became legislation in 1905. The U.S. Congress authorized the construction of the Elephant Butte Dam and Reservoir and the Rio Grande Project,⁸⁴ which were completed in 1916.⁸⁵ The 1904 plan also led to the ratification of a water allocation treaty with México in 1906. The agreement specified a monthly water allocation to México from the Rio Grande, for a total of 74 million cubic meters annually, to be delivered just above Ciudad Juárez. The provisions of the agreement also permitted the negotiated volume of water to be reduced owing to drought, but barred México from receiving more water in years of surplus (Convention

⁸³ Established through the Reclamation Act of 1902, the Federal Bureau of Reclamation was responsible for the funding and construction of 12 single-purpose irrigation projects and general waterworks in the 16 western U.S. states. The government had to negotiate with Texas for the development of new waterworks as it did not own or control land in the state, because Texas had been an independent republic prior to entering the union. Hence, the funding of projects had to take place with the acquiescence and support of private landowners in Texas, which did not occur until 1904. For the history of the U.S. Bureau of Reclamation and its eastern-seated rival, the U.S. Corps of Engineers, see: (Bagley 1961, Hundley 1967, Reisner 1986, Rogers 1993, Avalos and De Young 1995, Emel and Roberts 1995, Opie 2000, Lucero, Tarlock et al. 2003, Wurbs 2004)

⁸⁴ As highlighted by Littlefield (1999), it was the first congressionally-directed allocation of an interstate river in the U.S. This was 23 years before the Boulder Canyon Act of 1928 that apportioned the Colorado River, and which was mistakenly characterized as the first interstate river division accomplished through federal legislation by the U.S. Supreme Court in *Arizona v. California* (1963).

⁸⁵ The U.S. users of the system organized under two institutions charged with steering the water distribution system and coordinating payments to the Reclamation Service for its construction, operation and maintenance. Water users' associations in their origins, they soon reorganized as two irrigation "districts:" the Elephant Butte Irrigation District in New Mexico and the El Paso County Water Improvement District No. 1 in Texas.

for the Equitable Distribution of the Waters of the Rio Grande, 1906).⁸⁶ The amount of water allocated to México was established according to its irrigation requirements at the time of the signature of the 1906 agreement, which to this day remains the total volume of waters from the Rio Grande that Ciudad Juárez receives from the United States every year.

2) The 1938 Rio Grande Compact, the Rio Grande Rectification Project, and the 1944 Agreement

The institutions and waterworks that resulted from the 1904 compromise failed to put a definitive end to the disputes over the waters of the Rio Grande. Only a few years after the completion of the Elephant Butte Reservoir, the continued expansion of the Middle Rio Grande Valley and Colorado's San Luis Valley began threatening water deliveries in El Paso del Norte. The volume of water reaching Elephant Butte Reservoir was insufficient to ensure compliance with existing commitments. Residents of El Paso del Norte were again confronted with negotiating the allotment of the Rio Grande, although this time negotiations involved users in the upper sections of the Rio Grande Basin in New Mexico and Colorado.

Interstate negotiations started in 1928. During those negotiations, New Mexico requested the cessation of further upstream water diversions from the basin. It explicitly stated the threat that these activities posed to the Rio Grande Project and demanded the delivery of, at minimum, water sufficient to comply with its existing obligations.⁸⁷ Siding with New Mexico, Texas emphasized its reliance on the Rio Grande Project for the irrigation of 20,000 acres above Fort

⁸⁶ Wurbs (2004) notes that, since 1951, the United States has made use of the drought exception clause an average of once every three years.

⁸⁷ New Mexico noted that Colorado's San Luis Valley could fulfill its needs from a vast waterlogged area known as the *Closed Basin*.

Quitman.⁸⁸ Colorado, on the other hand, challenged the legitimacy of an existing embargo⁸⁹ on the upper Rio Grande and argued that all water diversions upstream would be compensated in return flows. It argued that the loss of water downstream was due to evaporation and not intensive use upstream. The impasse in negotiations led the three states to abandon them in 1929.⁹⁰

Domestic interstate discussions over the allocation of the Rio Grande resumed in the mid-nineteen-thirties. In 1935, Texas filed a lawsuit against New Mexico over failing water deliveries from the Rio Grande Project. Paradoxically, the lawsuit helped move negotiations

⁸⁸ Downstream from El Paso del Norte, the Fort Quitman section of the basin was at the time supplied by return flows of the Rio Grande Project. Reductions in the quantity of water reaching the project also affected sections of the basin located further downstream in México as well as Texas. The “Fort Quitman section of the basin” is now part of the “Hudspeth County Conservation and Reclamation District No. 1,” which still relies on so-called ‘tailwater’ – i.e. return flows from upstream irrigators (Hamlyn personal communication 07/2012).

⁸⁹ Since 1886, the Rio Grande Basin had been subject to an “embargo” by which new diversions from public lands were prohibited upstream. This embargo, a leftover of the tensions preceding the 1904 consensus, was deemed unfair by upstream users.

⁹⁰ Although they failed to reach a consensus regarding the allotment of the Rio Grande, Texas, New Mexico, and Colorado signed a temporary compact. The states agreed to cooperate in seeking federal funds for the drainage of the Closed Basin and the construction of a water reservoir at the New Mexico-Colorado border for the capture of any excess runoff derived from the operation. The compromise also established Colorado’s abstention from new water diversions or impairment of the river’s flow as it existed at the time. The temporary agreement relied heavily on federal funds, as well as on the idea that it did not hinder the position of any state. In October 1929, however, the U.S. economy collapsed, which put a hold on major federal expenditures for several years, in particular those necessary for the implementation of the *Temporary Rio Grande Compact*. In 1933, while the negotiations between Texas, New Mexico, and Colorado remained gridlocked, the U.S. and México struck a new agreement by which they decided to straighten and stabilize 250 kilometers of the Rio Grande in the El Paso-Juárez Valley. The *Rio Grande Rectification Project* also provided for the construction of a dam downstream of the Elephant Butte Reservoir, the *Caballo* dam. The new dam secured additional water for the Rio Grande Project, provided additional flood protection, and compensated for storage lost at Elephant Butte due to siltation. The Treaty included provisions for restoring and preserving the character of the Rio Grande as the international boundary, minimizing changes in the river’s channel, and solving problems associated with the position of the boundary line. The Treaty charged the IBWC with carrying out its provisions.

forward, as it prompted the direct involvement of President Franklin Delano Roosevelt and the National Resources Committee, a federal agency created in 1932 for the coordination of water development projects throughout the United States (Littlefield 1999).⁹¹ An investigative commission, *the Rio Grande Joint Investigation*, was then charged with the gathering and production of information about water demand patterns in the basin. In 1937, based on the information gathered by the commission, the three riparian U.S. states determined rules for the quantitative allotment of the Rio Grande, which they finally formalized in the 1938 through the *Rio Grande Compact*. In order to ensure the implementation of the compact, the states established a permanent commission, provided for the construction of measuring stations along the river to ensure water deliveries, and developed a system of debits and credits to deal with irregularities in the hydrologic budget.

In 1944, the United States and México concluded an agreement over the allocation of the Colorado River and the lower section of Rio Grande Basin, stretching from Fort Quitman, Texas to the Gulf of Mexico. The agreement resulted from years of bilateral and interstate negotiations (Hundley 1967); it established that México would deliver to the U.S. no fewer than 431 million cubic meters of water from the Río Conchos—this being the principal tributary of the Rio Grande/Río Bravo in the basin's lower section, where México is the upstream riparian—in exchange for approximately 185 billion cubic meters of water per year from the Colorado

⁹¹ In Reisner's blunt terms, the economic crisis of the thirties fundamentally transformed the criteria underlying the funding of water management projects. Waterworks were "*released from a need for justification*," "*released from logic itself*" (Reisner 1986:63). Competing U.S. federal agencies sought the intervention of every major watershed exhibiting a "*nearly pathological unwillingness to let go of even one river*" (Reisner 1986:215).

River.⁹² The 1944 agreement was particularly significant to the history of the management of transboundary waters between the U.S. and México because it also led to the revamping of the historic International Boundary Commission,⁹³ which it resurrected as the *International Boundary and Water Commission (IBWC)*. The binational commission was charged with the oversight and settlement of controversies over transboundary waters along the entire border (Mumme 2003, International Boundary and Water Commission 2007).⁹⁴ The treaty formally charged the IBWC with overseeing the implementation of bilateral agreements dealing with transboundary water resources; the intergovernmental body was empowered with a system of “Minutes”, detailed in Article 25 of the 1944 treaty, through which the U.S. and México could amend the terms and conditions of existing water-related international agreements. Minutes operate as binding addendums to the existing international water management agreements negotiated and implemented through the IBWC.

⁹² The agreement also allocated specific amounts of water from the Rio Grande’s fourteen major tributaries (Hurlbut 2001), and specified that any excess waters in the Rio Grande would be equally allocated between the two countries (Phillips 2002).

⁹³ Although the international boundary between the U.S. and México had been formally established in agreements signed in 1848 and 1856, its actual physical demarcation had not been completed by the end of the nineteenth century. In order to settle these issues, the U.S. and México created a joint commission in 1889, the International Boundary Commission (IBC), which they charged with the physical prospection and demarcation of the border (Timm 2010).

⁹⁴ The IBWC was responsible for the signature of the *Chamizal Convention* of 1963, which resolved the controversy over a “moving” section of the international boundary” at El Paso del Norte. The Chamizal dispute concerned 243 hectares a few miles south from downtown El Paso and Juarez. By 1970, the U.S. and México had resolved all pending boundary differences and provided for maintaining the Rio Grande and the Colorado River as the international boundary. (Lamborn and Mumme 1988, Mumme and Grundy-Warr 1998, International Boundary and Water Commission 2007).

3) Minute 242: The Entry of Qualitative Issues and Groundwater into the Political Agenda

Only two decades after the signature of the 1944 treaty, a new controversy arose between the U.S. and México over the allocation of the transboundary waters. By the nineteen-sixties, irrigation practices in the U.S. had led to the significant qualitative deterioration of the waters being delivered to México from the Colorado River, 780km west of the Paso del Norte region. The waters were unusable without significant treatment (Kibel and Schutz 2007). Mexican protestations met resolute U.S. declarations that the 1944 treaty failed to specify the quality of the delivered waters. In the face of this political gridlock, Mexican farmers constructed several hundred groundwater wells along the border. Farmers in the U.S. saw the Mexican water wells as threats to their own supply of groundwaters and demanded the inclusion of provisions concerning the use of shared groundwater resources in the negotiations over the quality of the Colorado River (Mumme 2003, 2005).

As a result, the signature in 1973 of IBWC's Minute 242 for the "*Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River*" included a number of provisions directly addressing the management of transboundary groundwater resources. The Minute not only established minimum quality standards for U.S. surface water deliveries to México, but it also imposed a quantitative embargo on groundwater extractions, explicitly prohibiting the extraction of more than 197 million cubic meters by any country in a specific section of the boundary between the U.S. state of Arizona and the Mexican state of Sonora.⁹⁵ The Minute also established that both countries would, in the future, inform each other of any development of the transboundary aquifers in that section of the border, pending the

⁹⁵ Minute 242 also envisioned a future comprehensive agreement dealing with groundwater resources in the border areas, which has not, to date, come to fruition.

conclusion of an agreement dealing with these resources along the entire border. Minute 242 was part of a series of new arrangements dealing with non-quantitative aspects of water management in the borderlands and focused on problems such as water quality and sanitation (Mumme 2005). It fostered dialogues about shared groundwaters along the U.S.-México border (Hayton 1978, Hayton and Utton 1989). The 1973 agreement exposed the critical importance of the resources, as well as the lack of regulations dedicated to their proper management, and highlighted the diversity of problems created by the increasing demand for water and the endemic scarcity of the resource at the border.

C - Groundwater Problems and Management Challenges

The history of the formal management agreements that regulate the use of surface waters at El Paso del Norte can be separated into two distinct phases. The first phase begins during the mid-nineteenth century with the signature of the agreements that demarcated the international border. It culminated in 1973 with the signature of Minute 242. This phase was marked by inter- and intra-national conflicts over the quantitative allocation of the resources and the creation of successive formal mechanisms for the resolution of controversies. The second phase was characterized by the recognition of qualitative issues and the systematic resolution of water management controversies through the Minute system of the IBWC. During this phase, a host of new issues entered the bilateral water management agenda but, remarkably, transboundary groundwaters were not among them. Despite the existence, functionality and flexibility of the IBWC – the product of the long history of water management at the border – and its demonstrated capacity to deal with transboundary groundwater resources, political authorities and water managers at El Paso del Norte have never engaged in official negotiations for the creation of a joint framework for the management of the resources. Groundwater problems

resulting from the intensive exploitation of the resources failed to trigger the conventional two-step: subsidiary politico-legal conflict and federal-level intervention. Instead, groundwater problems were tackled locally without resort to formal regulations.

1) Increasing Regional Groundwater Demand

The tumult of the politics revolving around the exploitation of the surface basins historically eclipsed the steadily growing role of groundwaters in the water supply of the communities located in the borderlands. The residents of El Paso del Norte started exploiting groundwater during the final decade of the nineteenth century (Nicoll 1951, Turner, Hamlyn et al. 2003). At the time, these resources were not just a convenient alternative to the dwindling waters of the Rio Grande, but the sole alternative. Groundwaters seemed free of most of the problems of surface waters: they were apparently unaffected by the vicissitudes of climate and presumably invulnerable to competing users. The first wells developed east of El Paso suggested that “there was an inexhaustible supply of water under the [Franklin Range] mesa” (Nicoll 1951, 53). By 1916, the amount of groundwater available appeared to be hindered solely by the cost of well drilling and the limits of pumping technology, and “the city of El Paso thought the water supply problem to be permanently and adequately solved for all time.” (p. 85). In 1921, the first report about water resources directly commissioned by the city of El Paso, the Lippincott Report, concluded that groundwaters would be sufficient to deal with the city’s future needs. By the nineteen-forties, largely independent from the legal and political conundrums associated with surface waters, local aquifers had become the principal source of freshwater for the cities of El Paso and Juárez.⁹⁶ With the majority of surface waters dedicated to agriculture, most of the

⁹⁶ Groundwater was virtually the only source of drinking water for the city of El Paso until a surface water treatment plant was put into operation in 1943 (Hamlyn personal communication 07/2012).

drinking water of El Paso del Norte was being tapped from the two major local aquifers, the Hueco-Bolsón Aquifer and the Mesilla-Bolsón Aquifer (Sayre, Livingston et al. 1945, Chavez 2000, Mumme 2005). As noted by Elaine Hebard, an attorney and environmental activist based in Albuquerque, New Mexico: “*We pretended that we had all this water... that it did not matter how much we took out (...) They were just not seeing the impact.*” (Elaine Hebard, Interview, March 4h 2010).

The progressive regional demographic and economic growth fuelled demand for groundwater. Demand rose with the permanent settling of workers and industries in El Paso del Norte, drawn by successive regional economic development plans: the Bracero Program during the early nineteen-forties, the Border Industrialization Plan and the Maquiladora Program during the nineteen-sixties, and finally NAFTA during the nineteen-nineties (Liverman 2004, 1).⁹⁷ Economic growth turned the historically sparsely populated region into one of the border’s most dynamic and heavily populated enclaves (Cervera Gomez 2007).⁹⁸ The region went from housing a total of about 24,000 inhabitants at the turn of the twentieth century to host more than 330,000 by the nineteen-fifties, and more than 2 million by the year 2000. The municipio of Ciudad Juárez expanded from 122,000 to 1.2 million inhabitants during the second half of the twentieth century, while El Paso County grew from 200,000 to 680,000 inhabitants (Turner, Hamlyn et al. 2003). In that period, Ciudad Juárez became one of the fastest growing cities in the world, growing at an average of 5.8 percent and functioning as a critical catalyst of the Mexican

⁹⁷ In El Paso, demographic growth was also fuelled by the extension of the local military base, Fort Bliss.

⁹⁸ Socio-demographic growth at El Paso del Norte led to the implantation of “colonias,” poor settlements with limited access to waters and the water distribution infrastructure and reliant on shallow groundwater wells and manual water transports. In El Paso, urban growth was also coupled with suburban development. Such development led to increased per capita water demand for the irrigation of non-productive lawns. (Hamlyn personal comm.).

economy (Fuentes-Flores and Cervera-Gomez 2004). Albeit at a slower rate, during the same period El Paso grew at an average of 2.5 percent per year (Turner, Hamlyn et al. 2003).

The ever-expanding demographic footprint and the limited availability of alternative sources of water in the area increased the pressure on regional groundwater resources, including the Hueco-Bolsón and Mesilla-Bolsón aquifers. Groundwater extraction rates actually grew faster than the population, increasing from approximately 35 million cubic meters per year during 1950 to more than 230 million cubic meters by 1990 (Chavez 2000). During the same period, the number of operating groundwater wells grew from 18 to more than 110 in El Paso, and from five to 142 in Ciudad Juárez (Chavez 2000, Alvarado-Venegas). By 2002, the total municipal and industrial water demand for the region—groundwater and surface waters—had increased to 370 million cubic meters per year (Brown, Browning-Aiken et al. 2002). The intensive exploitation of groundwater led to the noticeable deterioration of the local aquifers by the nineteen-fifties (Hutchison 2006), with the aquifers being affected by the development of water pumping infrastructure by the water utilities of Juárez and El Paso.

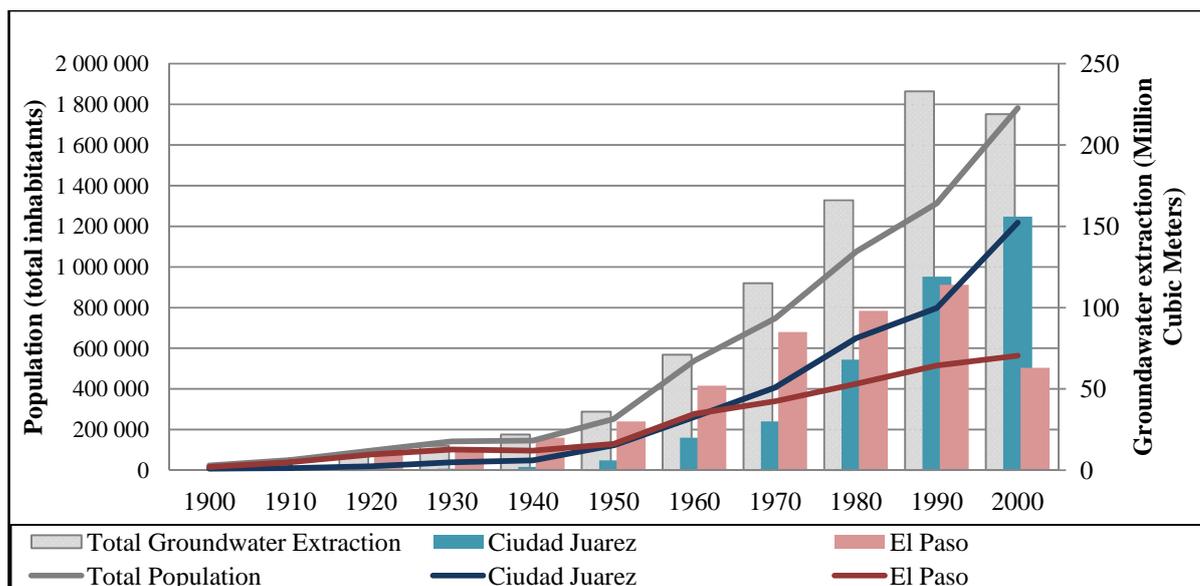


Figure 6: *El Paso del Norte: population and groundwater exploitation*

Source: Author from data in Chavez (Chavez 2000) and Franco Barreno (2009)

Groundwater over-draft triggered the slow but generalized drop of the water tables and the progressive contamination of groundwater wells (Chavez 2000, Archuleta 2010). The loss in storage was largely due to the scant recharge⁹⁹ and the unconfined nature of the local aquifers. The contamination of the groundwaters, on the other hand, resulted from non-point pollution from the cities located above the aquifers and the particularities of the local hydrogeology. Freshwaters account for just a fraction of the total regional groundwater reserves, which are mostly made of brackish waters. In fact, the main source of water of El Paso del Norte, the Hueco-Bolsón aquifer, stores freshwater only in a shallow irregularly shaped wedge that borders the Franklin and Organ Mountains and extends under the cities of El Paso and Juárez (Cliett 1969, Cliett and Hawley 1995, Sheng, Fahy et al. 2004, Hutchison 2006). The freshwater

⁹⁹ White (1987) estimated the natural recharge from the aquifer to be about 40 million cubic meters per year. It is largely based on mountain-front recharge, which is the percolation of surface run-off in the sections adjacent to bordering mountains. Meyer (1976) estimated mountain-front recharge by the Organ and Franklin Mountains in the U.S. and the Sierra de Juárez in México to be approximately 6.9 million cubic meters per year.

sections of the aquifer became progressively saline as wells drew waters of lesser quality from the deeper strata of the aquifer, a process known as ‘upwelling,’ and due to the lateral intrusion of brackish waters from surrounding lower quality aquifers. Under the pressure of increased demand, a number of water wells started drying up or became too heavily contaminated to continue supplying freshwater without significant treatment and infrastructural renovation.

As groundwater issues at El Paso del Norte gained political prominence due to the dire reports about the future availability of the resources in the region,¹⁰⁰ the regulation of groundwaters prompted concerns among regional stakeholders and political authorities. Groundwater regulation threatened the imposition of new restrictions on the access to the resources. At the same time, the new feasibility of groundwater agreements threatened established institutions of groundwater management as well as ongoing exploitation practices. El Paso del Norte’s groundwater problems articulated a technico-scientific component with a politico-institutional dimension.

2) Barriers to the Exchange of Information

The factors behind the deterioration of the local aquifers were relatively well known by local water experts by the time they became a problem for the users. Knowledge about the local resources grew throughout the first half of the twentieth century, rooted in the empirical investigation of the hydrogeological features of the region and the theorization of the factors influencing the behavior of the resources. Research on the hydrogeology of El Paso del Norte accumulated with the initial support of governmental agencies in the United States and in

¹⁰⁰ These reports were contemporaneous with the signature of Minute 242, which suggested, at least to regional legal scholars, that groundwaters would soon become a topic of the hydro-political discussions at the border. The agreement unleashed a paradigmatic change in the bilateral hydro-politics because it dispelled the notion that transboundary groundwaters could not be regulated (Hayton 1978).

México interested in the survey of natural resources, as well as with support from the regional universities, which offered resources and training courses for local hydrogeologists (Remson 2002, Hawley and Kernodle 2008). Scientists engaged in systematic and recurrent dialogues at the regional level and conducted extensive assessments of the hydrogeological features of El Paso del Norte and its vicinities. Their work contributed not only to the better understanding of the region but also to the general progress of the scientific discipline (Hutchison 2004, Hawley 2005). Dr. John Hawley, a prominent regional hydrogeologist, details some of the factors that, until the late nineteen-sixties, facilitated the development of scientific studies in the borderlands: *“I had a Department of Agriculture vehicle, a State Department passport... I could just drive right here... I could drive all the way down to Camargo, or the Conchos River with a team of Mexican scientists. We worked together as a team. Actually, if you look at the first soils survey in Chihuahua, I am listed as a co-author. (...) This was done in 1969. (...) With the official passports you could cross the border in 10 minutes. It was just an ideal time.”* (John Hawley, Interview, March 5h 2010)

Regional scientists identified the basic hydraulic linkages, volumes and sources of recharge, general geographical boundaries, and approximate quantity and quality of the groundwaters stored in the aquifers of El Paso del Norte (Meyers and Noble 1967, Hawley 2000, Hawley 2005, Hawley, Kennedy et al. 2009). They formulated basic models to describe the effects of groundwater exploitation on the relationship of the aquifer with the Rio Grande River and the status of water wells in Ciudad Juárez and El Paso (El Paso Water Utilities Public Service Board 2001, Hawley 2005). Early hydrogeological models highlighted, for example, that although the Hueco-Bolsón was originally a net contributor of water to the Rio Grande, the intensification of groundwater exploitation had, since the nineteen-fifties, reversed the

relationship between the river and the aquifer (Hutchison 2006). These models also demonstrated that uses of groundwater had consequences on both sides of the international border (Hutchison 2006, Creel 2009). By the early nineteen-seventies, to borrow a term suggested by Hawley, the scientists had already established the fundamental “hydrogeological truths” prevailing in the region. Ten years later, however, this scientific knowledge had yet not triggered new initiatives for the strategic co-management of the shared resources (Archuleta 2010). Although “the period of fantasy” described by Hayton (1978, 202) was largely over,¹⁰¹ the knowledge of the factors behind the aquifers’ decay failed to trigger the emergence of new groundwater management decisions.

a) Political and Institutional Challenges

The spirit of bilateral cooperation that had historically prevailed in the region all but disappeared during the nineteen-seventies. The decade was marked by the emergence of new barriers to the exchange of information about the resources. Official agencies withdrew funding and institutional support from regional hydrogeological cooperation initiatives and prohibited the exchange of data about the use of the resources,¹⁰² which included well-head pressure data, as well as information about water quality and the number and position of existing wells.¹⁰³ The

¹⁰¹ Hayton was referring to a period during which scientists and lawmakers lacked sufficient understanding of the resources.

¹⁰² The deterioration of the resources is shaped by the intensity of the exploitation.

¹⁰³ In México, beginning in the nineteen-seventies and at least until the late nineteen-nineties, the vast majority of water research and management was conducted by public organizations. Today, this information is still largely gathered by public agencies: the federal-level agency of water management (CONAGUA), state water boards (Comisiones de Aguas de los Estados), the urban and peri-urban water utilities (Juntas Municipales de Aguas), and local and regional universities. Conversely, in the United States, knowledge about groundwater resources is distributed among both public and private actors: federal agencies (U.S. Geological Survey, the EPA, the Bureau of Reclamation, the U.S. Corps of

decision reflected political tensions between the United States and México in the context of the Cold War¹⁰⁴ and the increasing recognition of the strategic role of hydrogeological knowledge in bilateral management negotiations. Based on their experience negotiating Minute 242, Mexican officials noted that the United States leveraged the extant knowledge about transboundary groundwaters to strengthen its position in bilateral discussions.¹⁰⁵ The use of joint research to serve political intentions was recognized as a threat, and both countries decided to restrict the bilateral exchanges of information about the resources. Dr. Hawley observes that the use of data in the negotiation of Minute 242 and the U.S. decision to limit bilateral cooperation had “*a huge psychological impact on Mexican scientists, and the government. They felt... I want to use a word softer than betrayed... but they were very disappointed.*” (John Hawley, Interview, March 5h 2010). Sally Spener, head of the Public Affairs Office of the IBWC, explains the countries’ reluctance to share information as a resulting from the risk that data highlighting a country’s responsibility for the deterioration of the resource might undermine the country’s position in international negotiations: “*Each country has an interest in making sure that someone from another country does not use the data in a way that would be inappropriate. So that someone can*

Engineers, etc.), local and regional universities, semi-private actors (irrigation districts and water utilities), as well as private actors (firms, consultancy firms, etc).

¹⁰⁴ John Hawley describes the situation: “*We [the United States] didn't really have an effective policy to share scientific information on natural resources. Certainly during the Nixon-Carter administrations, we were not encouraged to share.*”; “*Until Ronald Reagan was elected there was a period when we didn't really try to be good neighbors. That was because basically... it was part of the Cold War... a revolved over the fact that México always insisted in recognizing Cuba. They did not support the Bay of Pigs or anything. (...) so, these [joint-research] programs were all canceled.*” (John Hawley, Interview, March 5h 2010)

¹⁰⁵ Knowledge about the effects of groundwater exploitation at the Sonora-Arizona border was used to highlight Mexico’s responsibility in the deterioration of groundwater wells in the United States. It served as a counterpoint to the Mexican claim over the quality of the surface water deliveries from the Colorado River.

say: "AHA! This shows that you guys are responsible for all the pollution that we are experiencing in the United States" or "AHA! This shows that El Paso Water Utilities is increasing the salinity of groundwater in México" or whatever." (Sally Spener, Interview, March 22h 2010).

The process that led to the formalization of Minute 242 highlighted the political value of scientific information about the transboundary groundwaters. In fact, information about the resources was framed as a strategic asset for prospective bilateral water management negotiations. At the same time, however, the countries began questioning the real interests behind initiatives for the bilateral exchange of information. Mutual distrust resulted in the implementation of barriers to non-vetted exchanges among stakeholders at El Paso del Norte. Dr. Karl Wood, director of the Water Resources Research Institute at the University of New Mexico, notes that during the nineteen-seventies, the unauthorized exchange of scientific data about groundwaters was not just officially discouraged, but criminally liable to charges of treason; he claims that "*Mexico City threatened water people in Juárez, and along the border, that if they shared data with the United States they would be charged with treason.*" (Karl Wood, Interview, March 9h 2010). He further argues – not without sarcasm – that the distrust was reciprocal: "*CONAGUA has been viewed as a spy agency [in the United States]. They are really not interested in cooperatively working together... they are paranoid and only send people to the border to spy on us, and check what is going on because they don't trust us.*"

Dr. Ibañez, advisor coordinator to the Director of the Comisión Nacional del Agua (CONAGUA), explains that the agency's position was based on: "*the idea that the United States will always take advantage of the information, of its power, to make informed decisions.*" (Oscar

Ibáñez, Interview, February 23h 2010). This explanation echoes the claim of Helen Ingram, a political scientist dedicated to studying transboundary cooperation issues: “*Mexico's reluctance to engage in negotiations with the United States is because they believe that we have the ability to manipulate the science. Their insecurity about having the information that they need to go into negotiations is an impediment.*”(Helen Ingram, Interview, March 17h 2010). They both suggest that Mexican distrust was rooted in the fact that its participation in joint hydrogeological studies was never perfectly symmetrical. Scientists in the United States had access to financial and technological resources unavailable in México, which meant that research was historically driven by the scientists located in the United States. Dr. Oscar Ibañez notes that “*almost all the studies conducted in the region followed the initiative of American universities.*” (Oscar Ibáñez, Interview, February 23h 2010). Mexican authorities interpreted the limited technico-scientific capabilities of the country as a systematic political weakness. These statements not only emphasize the value of scientific information in processes of negotiation, but also demonstrate that knowledge about transboundary resources may not be free from political biases.

b) Few Venues for Scientific Cooperation

Despite the new barriers to cooperation, by the late seventies, the available information about the aquifers of El Paso del Norte suggested that the region could soon face acute water shortages. A report published in 1979 by the Texas Water Development Board, which was widely disseminated and editorialized by the media of El Paso del Norte, projected that the local aquifers would become unable to cope with the increases in demand within the first half of the

twenty-first century (Hutchison 2004).¹⁰⁶ Scott Reinert, Water Resources Manager at El Paso Water Utility, explains that the utility responded to the threats delineated in the 1979 report about the status of regional groundwater resources: “[*The report*] said that we were going to run out of water by the year 2030. (...) We realized we needed to start worrying about conservation. (...) It made us think that it was very important to start working and using surface waters... and it also made us think about cutting back on our groundwater pumping.”(Scott Reinert, Interview, March 22h 2010)

The report highlighted the fact that, although the amount of water available in the local aquifers could potentially suffice, the inevitable qualitative deterioration of the resources would eventually eliminate their economic viability. Local media outlets interpreted the dire projections of groundwater availability as omens of a looming water crisis in the region, which could potentially trigger future conflicts analogous to those historically associated with the waters of the Rio Grande (Coronado 1994, Hamlyn 2001, Archuleta 2010). In this context, projections of future water scarcity prompted a debate about the value of the resources and about the options available to cope with it: “*water planning is done during periods of drought. I mean, when we have plenty of snow melt and the river is full and there are no worries... you think you're going to be looking 50 years ahead and doing water planning? It is only when you start to see that the water is not coming out of your faucet that you start to wonder if it will be enough.*” (Scott Reinert, Interview, March 22h 2010)

¹⁰⁶ The section dedicated to the Hueco and Mesilla aquifers in the study was part of a more general report on groundwater resources in Texas and combined research conducted by the Texas Department of Water Resources, the U.S. Geological Survey and the City of El Paso.

While the acknowledgement of groundwater problems highlighted the importance of the resources and fostered the emergence of strategic plans to deal with their deterioration, it also emphasized the practical utility of having knowledge about the resources. The deterioration of the aquifers was recognized as a strategic political problem for the regional authorities as much as a concrete threat to the activities of the main suppliers of water in the region, the water utilities of El Paso and Juárez.

The implementation of measures to prevent the deterioration of the transboundary aquifer seemingly required the implementation of bilateral management mechanisms, which posed a two-fold threat. The need for such mechanisms implied the acknowledgement of respective responsibilities in the deterioration of the resources, as well as the subsequent reform of the institutional frameworks under which groundwater resources were being exploited. Texas allocates groundwater rights according to the *English doctrine* or *Absolute Rights doctrine*: private landowners have exclusive and absolute rights over the groundwater located on their property. Accordingly, the government of Texas and the U.S. federal government have limited jurisdictional power over the private use of the resources (Hardberger 2004, 1240-2, Wurbs 2004).¹⁰⁷ The regulation of groundwater exploitation by public authorities would require the significant reordering of the existing water rights and the revision of a large body of jurisprudence—in other words, the reform of the principles of groundwater governance in Texas

¹⁰⁷ Texas limits its control over groundwater rights to cases in which landowners pump groundwater with “malice or wanton waste.” (Mumme and Ingram 1985, 354). The limits of the reach of the U.S. federal government are not constrained by the state of Texas having adopted the Absolute Rights doctrine. Regarding the U.S. federal government, it lacks constitutional authority to regulate water use *unless* it constitutes some aspect of interstate commerce *or* (and this is an important ‘or’) commerce with foreign nations. Traditionally, the so-called “commerce clause” has been interpreted liberally (Hamlyn personal communication 09/2012).

(Evans 2005). Stakeholders in Texas rejected the intervention of the federal government not only on ideological grounds (Somma 1997), but also because of the institutional implications of such an agreement.

Mexican political authorities at the federal and local levels also preferred the flexibility of the unregulated *status quo* to a likely unfavorable regulatory framework.¹⁰⁸ Groundwater regulation could lead to new quantitative restrictions on the exploitation of groundwater resources. In light of the management history of the Rio Grande, Mexican authorities saw the risk inherent in such negotiations, recognizing Mexico's limited capacity to sway international negotiations with the United States in its favor, due to asymmetrical technical capabilities and insufficient political leverage. As noted by Szekeli (1986), México has generally opted for a "defensive approach" to negotiations with the United States over transboundary natural resources. With each side having its rationale for non-cooperation, the one common ground the stakeholders in El Paso del Norte were able to find was that an international agreement might not favor their interests. At the same time, they acknowledged the threats posed by the deterioration of the groundwater resources to their respective water supplies. Hence, while initiatives favoring the development of formal mechanisms for the management of the transboundary groundwaters were met with general reticence,¹⁰⁹ local stakeholders supported the reconstruction of the avenues

¹⁰⁸ Article 27 of the Mexican Constitution vests the ownership of all lands *and waters* within its boundaries to the state, and, through CONAGUA, the government does regulate extractions of ground water. It becomes a very different question whether the Mexican government would be willing subordinate itself to a treaty if this implied restricting access to ground water by its own citizens (Hamlyn personal communication 09/2012).

¹⁰⁹ Such an initiative was, for example, advanced by Carlos Ramirez, the U.S. Commissioner of the IBWC in 2001. "*Carlos Ramirez always threatened that he would write a groundwater treaty with México. The states of New Mexico, Arizona, and Texas just said that he could not write that treaty because he simply did not own that water.*" (Karl Wood, Interview, March 9h 2010); "*Commissioner*

for bilateral scientific cooperation.¹¹⁰ Although the regional approach to the management of the resources was seen as threatening and impractical, the absence of formal institutions regulating the management of transboundary groundwater at El Paso del Norte should obscure neither the effectiveness of the actions taken to deal with groundwater problems nor the progressive development of new venues facilitating regional-level coordination.

D - Competition over the Use of Groundwaters

In El Paso del Norte, the restricted access to information about the use of the transboundary aquifers led to a paradoxical situation: federal authorities and local stakeholders refused to exchange information that could help develop new formal bilateral agreements, but recognized that information exchanges were necessary to deal with the threats posed by the deterioration of the resources. In the political arena, information about transboundary aquifers operated as a negotiating asset: a tool that could provide leverage to sway bilateral negotiations, but also one that *in absentia* could help stall the formalization of new groundwater agreements. Yet the users of the resource in El Paso del Norte recognized that the technical understanding of

Ramirez, when he came in, started talking about a groundwater treaty (...) when he started going out to stakeholders talking about a groundwater treaty... they slammed the door in his face, figuratively.” (Sally Spener, Interview, March 22h 2010); *“A former commissioner of IBWC made off-handed comments at a meeting about a binational groundwater management framework in the U.S. states, and their general attorneys, went nuts.”* (Christopher Brown, Interview, March 11th 2010). Hamlyn observes that *“Interestingly, the effect of Ramirez’s surprise unilateral statements regarding the need for a ground water treaty may have prompted preparatory actions on the part of the Mexican Section. If so, this work was done quietly (unlike the blustery statements made by Ramirez to the press)”* He suggests the initiative echoed his lack of preparation for the position, rather than a realistic attempt at fostering such a groundwater agreement. Hamlyn further argues that Ramirez’ *faux-pas* actually encouraged preparatory actions on the part of the Mexican Section (Hamlyn personal communication 07/2012).

¹¹⁰ As noted by Sally Spener: *“I think each side feels, to a certain extent that they are benefiting from the lack of a regulatory framework. But also, beginning to see that data sharing and information sharing is beneficial so that we can accurately characterize the transboundary aquifers that exist...”* (Sally Spener, Interview, March 22h 2010)

the groundwater resources was necessary for the development of sound long-term water management plans. Local stakeholders thus favored informal dialogues for the exchange of knowledge and the unilateral management of the resources over the formalization of mechanisms for the coordination of management decisions.

1) Un-coordinated Groundwater Management Decisions

The development of new venues for the exchange of information across the international border was initiated by the main users of groundwater in El Paso del Norte, the water utilities, which were symmetrically under pressure to mitigate the effects of groundwater deterioration. The water utilities explored different management approaches to ensure the long-term water supply while finding alternatives to the progressively deteriorating and increasingly expensive waters of the Hueco-Bolsón aquifer. According to their respective technical and financial capabilities, the utilities prospected new sources of water, developed techniques and infrastructure for the utilization and reutilization of waters of impaired quality, and implemented measures for the reduction of water consumption by end-users. The water utilities acted autonomously, supported by information gathered unilaterally as well as through informal bilateral dialogues and semi-formal frameworks.

In 1980, El Paso's water utility (El Paso Water Utility, or EPWU) decided to install a new well-field to draw water from the Mesilla-Bolsón aquifer located a few miles west of the city center in the state of New Mexico.¹¹¹ The project was supposed to help the water utility reduce its reliance on the decaying Hueco-Bolsón aquifer; the new well-field would tap the neighboring

¹¹¹ The water utility has exploited the Mesilla aquifer since 1956, from deep wells in the unincorporated community of Canutillo, located in the far northwest corner of El Paso County—in a section barely overlaying the edge of aquifer.

Mesilla-Bolsón aquifer and significantly expand the volume of groundwater available for the city's supply. The success of the project hinged on the acquiescence of the Office of the State Engineer in New Mexico, the state political authority with jurisdiction over the allocation of groundwaters. The agency refused to grant El Paso access to New Mexico's groundwater resources and the Texan water utility challenged the decision in court (Earl and Czerniak 1996, Bath and Petit 1998, Archuleta 2010). Hamlyn explains that *“what transpired in the 1980s was an attempt by EPWU, then under General Manager John Hickerson, to gain access to a significantly greater share of Mesilla Bolsón. EPWU deliberately provoked a legal challenge to a New Mexico law that effectively barred interstate export of ground water. More than a decade of litigation and tit-for-tat acrimonious legal maneuvering followed. In the end, lawsuits were dropped as part of a negotiated settlement that left EPWU essentially where it had begun – namely without access to the Mesilla Bolsón other than the small, relatively ‘pinched out’ section of the Bolsón where EPWU continues to operate its Canutillo well field.”* (Hamlyn personal communication 07/2012)

The parties settled the dispute in 1991, after more than a decade of conflict. Scott Reinert, Head Engineer at the El Paso Water Utility stressed that *“as a result of the lawsuit, we don't work in New Mexico. Anymore. Ever. I mean, we are doing fifty-year water plans and it is not in the horizon. We are looking at the [aquifer located in the] Dell City area in 30 years, which is 100 miles east of town. (...) [But] we are not contemplating taking water supplies from there [New Mexico].”* Yet despite the opposition of New Mexico's State Engineer, today both El Paso Water Utility and the water utility of Ciudad Juárez – the *Junta Municipal de Agua y Saneamiento (JMAS)* – tap groundwaters from the Mesilla-Bolsón aquifer. In 2011, the water utility of Ciudad Juárez completed the installation of new infrastructure for the exploitation of

the Mesilla-Bolson aquifer, known as the Conejos-Medanos aquifer in México.¹¹² Water wells are located some 40 kilometers west of Juárez, in the Ascención municipio, and waters are conveyed to Juárez through an aqueduct. The Texas water utility bypassed the veto of the New Mexico State Engineer in the late eighties through the construction of a well-field on the Texas side of the Texas-New Mexico border, the *Canutillo* well-field, which currently produces approximately 30 million cubic meters of water per year and supplies nearly 25 percent of El Paso's total water demand.

Nevertheless, as a consequence of the dispute, El Paso Water Utilities modified its general water management strategy, from one relying mainly on groundwaters to one with a greater emphasis on surface waters and water conservation: “*We diversified our water resources, we increased the use of surface waters, we stopped pumping the aquifer as much and we got conservation and reclaimed water.*”(Reinert). In addition, it developed water treatment infrastructure for enhanced wastewater management and for water reutilization, which allows the secondary and tertiary use of the waters (Archuleta 2010). Reclaimed water is directly used for non-potable purposes – e.g. agriculture, landscape irrigation (primarily parks), and industrial use. It is indirectly used for drinking water purposes after being either pressure injected into the Hueco Bolsón (at the Fred Hervey Reclamation Plant) or by discharging treated effluent (from the Northwest WWT plant) into the Rio Grande less than a kilometer upstream of its diversion into an irrigation canal, from which (about 4.5 km downstream) water is withdrawn to feed the Utilities' Robertson/Umbenhauer water treatment plant (Hamlyn personal communication

¹¹² The Office of the New Mexico State Engineer asserted in 2001 that the planned Mexican exploitation of the Mesilla-Bolsón aquifer posed “a potential international threat” to New Mexico's water supply and said that it would consider reducing surface water deliveries to México to compensate for the impact of the increased exploitation of the transboundary aquifer (SAHRA nota 15).

07/2012). In addition, EPWU has implemented aggressive water conservation campaigns and built the world's largest inland groundwater desalination facility (Hutchison 2006). As noted by Reinert: *“all those technologies allow us... it is like adding a new source of water. Adding a new well-field, adding a new water intake on the river.”*

On the other side of the border, conditioned by more limited financial resources but free from the inter-state challenges, the water utility of Ciudad Juárez (JMAS) has tackled the challenges of groundwater deterioration with similar tactics. It prospected alternative sources of groundwater, improved water conveyance systems, developed infrastructure, and fostered water conservation (Cervera Gomez 2007). Dr. René Franco, environmental consultant for the city of Ciudad Juárez, specified that *“[water conservation was encouraged] in the first place, I must say, financially... We installed water meters in the entire city. Then, when people noticed the waste, things changed. You shut off the faucets. In the second place, the city's hydraulic system was much improved: new valves, new conduits have stopped leaks and saved a lot of money. But besides, the city has implemented a very intense educational campaign. It had a huge effect on people and consumption has decreased more and more.”*(René Franco Barreno, Interview, March 8th 2010)

Water management actions implemented in El Paso and Juárez during the past twenty years have reduced the stress on the Hueco-Bolsón aquifer. In a report published in 2004, El Paso Water Utility re-examined the flow and quality of the groundwaters stored in the Hueco-Bolsón and challenged the dire scenario advanced in the 1979 report: re-calculating the total freshwater reserves of the Hueco-Bolsón aquifer, it extended its projected lifespan by approximately seventy years (Hutchison 2004). This assessment was validated by the water

utility in Juárez (Servicio Geológico 2010). Despite the absence of an agreement dedicated to the coordination of actions for the protection of the transboundary resource, local stakeholders have implemented management measures that have accomplished that goal.

2) Informal Cooperation Venues

The development of water management activities in El Paso del Norte has been rooted in diverse mechanisms of dialogue and cooperation between local stakeholders. These mechanisms include bilateral dialogues between the water utilities, as well as multi-stakeholder forums that involve water managers, regional scientists, public authorities and private actors. The development of these mechanisms, as stressed by Reinert, stemmed from the symmetrical threat posed by the deterioration of the aquifer: *“We are planning to use the Hueco-Bolsón for 100 years, hundreds of years. If we are going to use it to point where we are going to exploit it and ruin it then that is not good management on our part. I believe our Mexican counterparts would agree with this concept.”* (Scott Reinert, Interview, March 22h 2010).

The settlement of the controversy between El Paso Water Utilities and the Office of the State Engineer in New Mexico led, for example, to the creation of a “Joint Settlement Commission.” The Commission sought to harmonize the water management strategies of the Office of the State Engineer in New Mexico and the water utility of El Paso (City of El Paso, Elephant Butte Irrigation District, and New Mexico State University “Settlement Agreement” 1991). Later rebranded as the New Mexico-Texas Water Commission, the body evolved into a forum for a wider range of the regional stakeholders involved in interstate water resource management, including university scientists and policy makers—members of regional irrigation districts, city water utilities, and federal agencies (Brown, Browning-Aiken et al. 2002). Although the

Commission did not possess any binding authority, it became a space for the systematic exchange of information about strategic water planning between stakeholders in New Mexico and Texas.¹¹³

Multi-stakeholder forums complemented the ongoing informal dialogues of the water utilities that first developed in the mid-nineteen-eighties. Zuping Sheng, hydrogeologist at Texas A&M University and former employee of El Paso Water Utilities, explained that: *“When I was working at the utility, we were partners with the water utility in Juárez. We looked at current conditions and the potential future impacts of pumping or future water resources planning and management (...) I was working essentially as staff for the utility to share and exchange information. I tried to understand the system more closely from a utility perspective. What are the future needs, what is the future supply, what is the potential impact of groundwater pumping or limited groundwater pumping...”* (Zhuping Sheng, Interview, March 22h 2010).

The identification of the common management challenges facilitated pragmatic exchanges between the water utilities about the use of the resources and their respective water management

¹¹³ A similar initiative that, unlike the Commission, included Mexican stakeholders, developed toward the late nineteen-nineties. In 1998, researchers at the Houston Advanced Research Center (HARC), New Mexico State University, and the Universidad Autonoma de Ciudad Juárez obtained funding from the Hewlett Foundation for the development of a new regional institution dedicated to the regional management of water resources, similar in tone and scope to an existing informal task force that dealt with transboundary air quality issues (Brown 2002, Rincon). The initiative paved the way for the creation of the Paso del Norte Water Task Force, an informal advisory body for the decision-makers of El Paso del Norte on water management issues (PDNWTF 2001). Its members included the regional water utilities, irrigation districts, university researchers, non-governmental organizations, and private-sector stakeholders from both sides of the border. The Task Force compiles detailed scientific data concerning regional water resources, facilitates the informal exchange of data among its members, and serves as a neutral space for the debate of new approaches and problems of regional water management (PDNWTF 2001). Unfortunately, the Task Force held its last meeting in 2010, and it is unclear whether it remains a viable forum for exchange.

strategies. As noted by Franco, despite the lack of a formal mechanism for the coordination of water management actions and the exchange of information: *“the water utilities communicate all the time. We have great communication, albeit via informal channels.”*(Franco)¹¹⁴. Yet this pragmatic exchange of information between the water utilities, besides supporting autonomous decision-making processes, also clarifies the limits of the dialogue: *“In order to keep it from becoming official, they said: ‘ok, I’ll give you a copy, and you can give me a copy... little by little bi-national exchanges increased. To the point, where today the utilities have met; they had meetings. They know their limits, they know how far they can go, but they also know what can be done informally.”* (René Franco Barreno, Interview, March 8th 2010)

These exchanges turned into semi-formal cooperation frameworks in 1997 and 1998, when the water utilities of Ciudad Juárez and El Paso signed two agreements under the auspices of the International Boundary and Water Commission for the exchange of data to update and refine the hydrogeologic characterization of the Hueco-Bolsón aquifer. Respectively, these agreements were titled the *“Joint Report Of The Principal Engineers Regarding Information Exchange And Mathematical Modeling In The El Paso, Texas And Ciudad Juárez, Chihuahua Area Aquifer”* of 1997, and the *“Transboundary Aquifers and Binational Ground Water Database For the City of El Paso / Ciudad Juárez Area Report”* of 1998. The water utilities also signed a memorandum of understanding through which they committed to exchange information concerning their respective groundwater exploitation and strategic water exploitation plans. Franco concludes that, as a result of these agreements and the dialogues between the water utilities: *“The attitude*

¹¹⁴ *“tenemos mucha comunicación de las juntas de aguas. Tenemos una comunicación estupenda, fuera de libreta. Es un arreglo que tenemos.”*

has changed tremendously... before we would... we would build a well and keep the data. We hid it so that no one would know. (...) but not anymore... We have communication now.” (Franco¹¹⁵)

3) Recent Cooperation Initiatives

The diplomatic relations of the U.S. and México have improved significantly since the nineteen-eighties. The countries have struck several agreements aimed at improving bilateral cooperation and fostering economic development and environmental protection. This amelioration of bilateral relations eased restrictions on the exchange of hydrogeologic information in El Paso del Norte. Although new formal bilateral agreements have neither directly addressed groundwater protection issues nor favored the regulation of groundwater exploitation, they have created a more certain scenario for investments in regional water management infrastructure and helped attract federal funding to the region (Gilberto Esqueda Director at Suez-Degremont in Mexico D.F., Interview, February 24h 2010).¹¹⁶

In 1983, the countries signed the La Paz Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area. Championed by the Reagan administration, the goal of the agreement was to improve and institutionalize bilateral cooperation initiatives for

¹¹⁵ *La actitud ha cambiado tremendamente... antes era casi... te explicó así... hacíamos un pozo y guardábamos los datos, los escondíamos para que no se dé cuenta nadie. Con un celo Espantoso. Y ahora no. Ahora hay comunicación.*

¹¹⁶ EPWU has since then successfully attracted federal funding for a number of major infrastructure projects, such as the enlargement of the Jonathan Rogers surface water treatment plant, developing a water reclamation system, and constructing its desalination plant. In Mexico, the Junta Municipal has successfully promoted the development of two new large wastewater treatment plants, projects known as the North-North and South-South wastewater treatment plants, as well as a new water well field from the Mesilla Aquifer, through a mix of private a public funds.

the resolution of environmental problems along the U.S.-México border.¹¹⁷ It empowered federal environmental governance authorities in the U.S. and México to develop bilateral cooperation initiatives and new formal mechanisms for the protection of the environment (Li, Arnold et al. 2005). A decade later, in 1993, the signing of the North American Free Trade Agreement (NAFTA) between México, Canada, and the United States was accompanied by the establishment of four major institutional mechanisms dedicated to the resolution of environmental problems at the border: the Border XXI Framework, the Border Environment Cooperation Commission (BECC), the North American Development Bank (NADBank), and the Commission for Environmental Cooperation (CEC) (Frisvold and Caswell 2000, Arnold and Buzás 2005). These formal bilateral cooperation institutions provided much of the funding for water management projects in El Paso del Norte, thereby supporting the unilateral and subsidiary governance of the groundwater resources.¹¹⁸ Yet despite their relative success in aiding the development of cooperation and infrastructure at the border, these formal venues did not change the fundamental rationales informing local stakeholders' rejection of a formal agreement for the joint management of transboundary groundwaters. What this new history of cooperation in El Paso del Norte did lead to was the emergence of social networks that eventually fostered the formal recognition of local-level practices at the federal level.

¹¹⁷ At the time, the United States and México recognized that the implantation of Maquiladora industries at the border was encouraged by not only the competitive cost of labor in México, but also the less-restrictive nature of its environmental regulations. The situation was associated with increasing environmental deterioration at the border, which included, in particular, the contamination of groundwater resources from industry-based pollutants.

¹¹⁸ These institutions provided some funding directly through the Border Environment Infrastructure Fund – these funds primarily for planning and engineering costs - and through NADBank. NADBank, due to its relatively high interest rate loans, was less a factor than it might otherwise have been, particularly on the U.S. side of the border. Some agencies (particularly EPWU) made use of the BECC certification process to seek funding from other, non-NADBank sources (Hamlyn personal communication 07/2012).

In 2006, the U.S. government passed an Act that appropriated funds for the scientific assessment of transboundary aquifers along the U.S. border (not including California¹¹⁹). Although it could become the basis of a joint management agreement for transboundary groundwaters along the border, such an agreement is not the goal of the project. The U.S. Congress passed the “Transboundary Aquifer Assessment Act” to encourage and fund research on the transboundary groundwater resources along the U.S.-México border. The Act provides financial support for the regional universities to develop joint research projects on transboundary groundwaters. Karl Wood explains the process that led to the creation of the Act: *“In 2003, Sen. Jeff Bingaman from New Mexico... his staff called me up and said that they would like to have what is called a Senate Field Hearing. (...) At the end of that day, we had a short meeting and he said: the number one problem we have is that we don't know how much groundwater we have, where it is, how deep it is, how thick it is, which way is moving... and whether this is good or bad. He said: we have lots of well data but we haven't really put it all together. I said: ‘that is right.’ So, he had a staffer named Mike Connor... he and I wrote that bill. (...) Today [Mike Connor] he's the head of the Bureau of Reclamation. He's a young man from Las Cruces, got a bachelors degree in mechanical engineering here, then that got a law degree from the University of Colorado, I think, and went to work as a legal counselor for the energy committee. Sen. Bingaman and Sen. Dominici were the ranking members of that committee.”* (Karl Wood, Interview, March 9h 2010).

The Act is a program to characterize, map, and model groundwater resources along the border. It provides for the development of joint scientific investigations into the status of

¹¹⁹ California was not included due to an ongoing dispute with México over the concrete lining of the All American Canal, which affected the recharge of the transboundary aquifers.

“*priority transboundary aquifers*” through the creation of geographic information system databases and agreements and partnerships between water management authorities—*i.e.*, the U.S. Geological Survey, participating states, water resources research institutes, the International Boundary Commission, and Mexican authorities. The information produced by the initiative is supposed to serve the water managers and natural resource agencies in charge of dealing with the Hueco-Bolsón and Mesilla aquifers, the Santa Cruz River Valley aquifers, and the San Pedro aquifers. However, the Act explicitly prohibits the development of field studies without the participation of the water resource agencies with jurisdiction over the aquifer, as well as the modification of either the jurisdiction or responsibility of existing authorities, the private water rights to the transboundary aquifers, or the water laws, interstate compacts and international treaty governing the resources.

In fact, despite the improvement of the aquifer’s status and the amelioration of bilateral relations over the past thirty years, authorities are still threatened by initiatives for the official joint assessment of the aquifer. Christopher Scott, political scientist at Arizona State University’s Udall Center, notes that in reaction to the passage of the Act: “*Mexico is saying: ‘wait, there is a U.S. legislation, the U.S. program, how can we become a part of that if we don't have any formal agreements on our side to do that.’ (...)* the Junta de Aguas de Chihuahua and some state actors from Chihuahua and the Sonora representatives said that this was part of the ‘*autoridad federal*’ and we could not say much. The U.S. position, the interest of New Mexico, Texas and Arizona was to have some agreements around groundwaters... information sharing but also some institutional assessments, growth assessments, economic drivers... but you know, these things that are not purely technical issues.” (Christopher Scott, Interview, March 16th 2010).

The threats associated with the official assessment of the shared resources remain not in the exchange of information between the parties at the local level, but rather in the potential use of that knowledge for the formalization of a bilateral agreement.

E - Conclusion: Unilateral Management

During most of the nineteenth century, the waters of the Rio Grande were sufficient to deal with the incipient but growing needs of El Paso del Norte. As waters dwindled, however, securing the water supply became a matter of utmost concern for the residents of the region. In that context, water management institutions emerged as means to contain conflicts and establish more certain scenarios for decision-making. Water management initiatives reflected the increasing expansion and institutionalization of the federal government in the U.S. and in México, and the issues addressed by these initiatives concerned the demarcation of the boundary as much as the establishment of the federal government's relationship with local-level political authorities. The federal government also arbitrated interstate and international water management disputes.

Moreover, the emergence of water management mechanisms fostered economic and demographic growth at the local level. The tumult of the hydropolitics associated with surface waters eclipsed the quiet but increasingly intensive exploitation of groundwaters along the borderlands, which was driven by economic and demographic growth. The exploitation of these transboundary aquifers helped compensate for the limited regional availability of surface waters. As opposed to surface waters, groundwaters appeared free from quantitative restrictions and the challenges created by competing users. Advancements in water-pumping technology and the knowledge of the region's hydrogeology supported the increasing exploitation of the resources.

Yet despite the increasing reliance on groundwater resources in the borderlands, their use long remained outside the political agenda. Although at first it was merely limited understanding of the effect of intensive exploitation on the resource that kept political recognition of groundwater use at the margins, stakeholders later perceived threats to their interests that were inherent in the

regulation of the groundwaters, which counterbalanced other incentives to bring groundwater use into the political arena. The formalization of a bilateral agreement for the management of the transboundary aquifers of El Paso del Norte threatened established institutions and the vested interests of local stakeholders. In that context, the development of new knowledge about the resources was inextricable from the recognition of the technical and political challenges associated with their governance. The legacy of water management institutions and the asymmetric scientific-technical capabilities of the U.S. and México suggested that a new agreement would be unlikely to favor the parties equally. Moreover, a new formal agreement would require the reform of existing institutional frameworks, adding greater uncertainties to the outcome. No stakeholders from either side of the border could ensure that the outcome of bilateral negotiations would result in a situation more convenient than that of the *status quo*. In other words, subsidiary authorities resisted the formulation of water management instruments because they could not ensure the outcome of the process. The paucity of reciprocal knowledge about the groundwaters on both sides of the border was instrumental to stalling new formal bilateral negotiations, but, at the same time, to driving a silent process of pragmatic cooperation that emerged among the stakeholders at El Paso del Norte.

Despite the barriers to the emergence of coordinated regulation for the transboundary aquifers, unilateral actions aimed at the mitigation of groundwater problems have multiplied over the past 30 years. The deterioration of the resources prompted the main users of the resources, the water utilities of the cities of El Paso and Ciudad Juárez, to reduce water demand and develop alternative sources of water. They prospected the Mesilla-Bolsón Aquifer, located a few kilometers west of the sister cities, developed new water treatment facilities, and fostered the conservation of water resources. Their actions dispelled the threats attached to the ‘water crisis’

scenario. Significantly, the utilities' water management decisions were not based on legal mechanisms similar to Minute 242 or any other formal bilateral coordination mechanisms. Instead, the challenges of transboundary groundwaters were addressed unilaterally. In place of a framework for the co-management of the resources, several informal information-sharing mechanisms and semi-formal arrangements facilitated the exchange of information and the coordination of decisions in El Paso del Norte. Despite the lack of an agreement for the management of the transboundary aquifers, sustained informal exchanges silently fostered the emergence of social networks that have effectively averted conflict and coordinated measures for the protection of the shared resources.

In this case, despite the recognition of transboundary groundwater problems, systemic and socio-institutional factors conspire against the formulation of coordinated mechanisms for the management of the shared aquifers. Significantly, stakeholders from both sides refuse to formally engage in the joint-management of the Hueco and Mesilla Bolsón Aquifers. The unilateral management of the aquifer reflects the particular framing of the shared problems under the light of existing institutions and power asymmetries.

VII - The Guaraní Aquifer System

A - Introduction

October 19th 1979, in the city of Asunción, the Presidents of Argentina, Brazil and Paraguay gathered to sign an agreement that established general principles for the utilization of the Paraná River, shared by the three nations. These principles were directly instrumental to the construction of hydroelectric centrals, as well as to the pacification of the tensions raised by the competitive exploitation of the watershed by the riparian countries. The 1979 agreement framed water resources as the object of geopolitical competition and was instrumental to the goals of centralized economic development plans. Starting in the nineteen-eighties, however, changes in the global paradigms of environmental governance and in domestic politics modified both the countries' approach to international environmental governance and the tone of their international relations: the 1979 agreement would be the last of its kind. The priorities of international cooperation soon became those of the protection of democratic governments, environmental protection and subsidiary economic development. Water governance initiatives came to reflect new regional political circumstances and the empowerment of new actors at different levels of governance.

In 2003, the same three countries and Uruguay engaged in yet another cooperative process for the joint management and protection of shared waters. This time, however, the initiative dealt with the groundwaters stored in the Guaraní Aquifer System (GAS), a large transboundary aquifer basin spanning beneath the four countries.¹²⁰ The countries, with the support of the

¹²⁰ Located under the Paraná, Uruguay and Paraguay River basins, the Guaraní Aquifer System extends over 1.1 million square kilometers. Unconfined in its northern sections, it becomes confined and is found

World Bank, engaged in a cooperative initiative aimed at “the joint creation and implementation of an institutional, legal and technical framework for the management and preservation of the Guaraní Aquifer System for present and future generations” (SGSAG 2005). By the end of the decade, the process had led to the implementation of several internationally coordinated policies at the local level, to significant changes in the region’s water laws, and to a framework international agreement between the countries dedicated to the governance of the Guaraní Aquifer System.

at increasing depths in its southern sections. The quality of the groundwater varies across different locales, but is generally suitable for immediate consumption without significant treatment.



Figure 7: The Guarani Aquifer System

Source: Adapted from Favetto et al. (2011)

Despite the magnitude and importance of the groundwater reservoir, mentions of the GAS only surfaced in the nineteen-eighties. Although the shared freshwater reservoir had been utilized at least since the nineteen-thirties, it had somehow escaped regional discussions about water

resources. The entry of the GAS into the political agenda, the international cooperation initiative aimed at its integrated management, and the specific policies that resulted from the project were products of institutional reforms and the evolving interaction of regional scientists, international organizations, and public officials. Why was the GAS unknown until the nineteen-eighties? Was the emergence of a cooperation initiative aimed at its governance similar to previous experiences of water management in the region? More generally, what were the paradigmatic and political factors underpinning the identification of the large transboundary groundwater basin? How did the countries manage to develop a formal framework for the management of the resources?

This section addresses the factors that shaped the emergence of new knowledge about the GAS and this knowledge's role in the creation of new groundwater management mechanisms. It looks at the elements that contributed to the conceptualization of the Guaraní Aquifer system and the formulation of the *Project for the Environmental Protection and the Sustainable Management of the Guaraní Aquifer System* (GASP), launched in 2003 by Argentina, Brazil, Paraguay, and Uruguay. It considers groundwater resources simultaneously as a matter of scientific research and a subject of policy and argues that the emergence of a governance framework for the Guaraní Aquifer System resulted from the strategic conceptualization of the regional groundwaters by non-state actors and international organizations, a process that was fuelled by the significant transformation of the rationales driving international cooperation initiatives in the region.

The argument is that the formal framework for the joint management of the GAS resulted, in the first place, from domestic institutional reforms, which facilitated the emancipation of the regional universities from centralized State decisions. Democratization fostered the emergence of studies dedicated to hydrogeology and the development of new scientific networks in the region.

These networks then fuelled the entry of groundwaters into the political agenda through linkages with international organizations and domestic political authorities. Knowledge about the region's aquifers was strategically mobilized to encourage the intervention of international organizations and the States. The formulation and implementation of the GASP was largely driven and influenced by the preferences of non-state actors and decentralized authorities seeking practical solutions to localized groundwater problems, rather than the strategic preferences and centralized development goals of the riparian States. Simply, the recognition of regional groundwater problems was concomitant with the constitution of new political actors, interested in the emergence of management mechanisms for the shared groundwaters.

Through the examination of the context and rationales at work in the discovery and politicization of the GAS, this section aims to contribute to the analysis of the roles of cognitive factors in environmental governance. These factors are constitutive to the emergence of policy and are receiving increasing attention in the literature dedicated to environmental governance, yet they are too often ignored or sidestepped in conventional analyses of international relations, which take knowledge of the policy problems and the geopolitical threats associated with them as known and given. Tracing innovation in knowledge and in the factors that drive innovation is particularly useful to understand the increasingly critical role of non-state actors in international politics. The goal of this chapter is to examine the complex relationship between changing institutional and political paradigms, the practice of hydrogeological research, and the development of transboundary groundwater management policies. It argues that paradigmatic changes at large can be traced to the reform of academic institutions and the interactions of regional scientists with international water policy-making initiatives. Moreover, it stresses that

understanding the factors behind the politicization of the Guaraní Aquifer System can better explain the complex factors that shape global environmental governance.

The development of a governance framework for the Guaraní is presented in three steps. The first introduces the history of regional hydropolitics, its principal features and founding principles. It describes the historical and institutional context that shapes regional water governance initiatives. Specifically, it examines the structural and paradigmatic transformations that reshaped the decision-making processes underlying regional water governance decisions. The second step focuses on the politicization of groundwaters in the region. It deals with the concrete factors that led to the discovery of the GAS and the formulation of the GASP. It deals, in particular, with the role of the new actors empowered by democratization. It analyzes the rationales and the relationships between regional hydrogeologists, government officials and international organizations. The third and final step describes the GASP and the outcomes of the project. It also reviews the environmental governance policies that derived from the project.

B - Hydropolitics and Power Struggles in the La Plata River Basin

During the colonial period, South American river basins were mainly employed as means of communication. Juan de Garay, the second founder of Buenos Aires,¹²¹ claimed that the port city of Buenos Aires had to “open the doors to the land:” fluvial communication was instrumental to the conquest and control of the territory (Barager 1959). Later, independence from the European empires in the early nineteenth century added a new function to the shared waters: rivers became international boundaries.¹²² The Río Paraná and the Río Paraguay separated Paraguay from Argentina and Brazil and also formed part of the Brazil-Bolivia border; the Río Pilcomayo separated Paraguay from Argentina, and the Río Uruguay separated Argentina from Brazil and Uruguay. Wars and post-colonial competition transformed the riverside borderlands into significant areas of geopolitical tension (Burr 1955,41). Later, the decay of the liberal-conservative paradigm (Zimmermann 1995, Cervo 2003),¹²³ which was prevalent from the end of the nineteenth century until the economic crisis at the beginning of the 1930s, shifted the focus of regional hydropolitics. The regional watersheds, in addition to their role as means to demarcate territory, became instruments of economic development. By the early nineteen-thirties, international waters were core components of the regional developmentalist policies; conflicts over the shared water resources, which were previously associated with the consolidation of the regional states, gave way to international cooperation projects aimed at

¹²¹ The first attempt to settle Buenos Aires in 1536 failed due to resistance of the local tribes. Juan de Garay succeeded in 1580.

¹²² Although several minor border disputes persist, they are unlikely to generate significant tensions between the countries. For more details, see (Goertz and Diehl 1992, 142) p. 141-142. (Elhance 1999) p. 38-40.

¹²³ The liberal-conservative paradigm refers to the philosophico-political rationale driving the decision-making of political elites at the turn of the twentieth century, which generally favored economic liberalization but restricted socio-political inclusion.

fostering economic growth (Russell and Cisneros 2000). Until the late nineteen-seventies, the majority of regional bilateral and multilateral agreements directly or indirectly involved aspects related to the management of the waters of the Paraná-La Plata Basin (Burr 1955,94-96, Resende-Santos 2002,37).

The conflation of geopolitical and economic considerations in regional politics is visible in the myriad of water-related agreements signed by Argentina, Brazil, Paraguay, and Uruguay throughout the twentieth century. These agreements included large framework treaties that established principles governing the use of the shared resources as well as specific agreements for the implementation of waterworks in the Paraná-La Plata basin. With 3.2 million square kilometers distributed in the Paraná, Paraguay, and La Plata rivers and their tributaries, the watershed is the fifth largest basin in the world, and the second largest in the western hemisphere. Although the meanings and stakes attached to the shared waters evolved over time, the old meanings did not necessarily fade away, as much as they adapted to new political priorities. Even if new negotiations focused on rights to exploit the shared water resources, the historical role of water and its geopolitical considerations remained key issues underlying negotiations. Over time, however, the main role of the regional river basins as means to demarcate national territories and to communicate was replaced by other functions: regional economic development and democratic consolidation.



Figure 8: The Paraná- La Plata Basin
 Source: Adapted from Elhance (1999, 27)

1) Water Management Agreements

In December 1933, following the 7th Inter-American Conference held in Montevideo, the basin riparians agreed on the adoption of a Declaration on the Industrial and Agricultural Uses of International Rivers, the *Declaration of Montevideo*. In this agreement, the countries recognized the validity of the principles of prior consultation and equality for the management of the basin, which became the normative basis of all water management agreements in the region. The Declaration reflected the growing interest in the use of the water resources for economic development as well as the need to implement management rules to avoid conflict among the riparians. Based on these principles, Argentina and Uruguay signed a bilateral agreement in 1946 for the joint construction of a hydroelectric dam on the Uruguay River, the Salto Grande dam, which was the first joint project dedicated to the international exploitation of the basin. It would be followed by several similar bi-national infrastructure development projects.

Two decades later, in February 1967, multiple interventions in the basin led to the negotiation of a new set of principles for the governance of the shared waters. Following the establishment of the *Committee for the Intergovernmental Coordination of the La Plata Basin (CIC)*, Argentina, Bolivia, Brazil, Paraguay, and Uruguay signed the *La Plata Basin* treaty in April 1969, through which they explicitly stated the political and economic stakes attached to the resources of the basin (Russell and Cisneros 2000). The Treaty also established formal mechanisms for conflict resolution and the systematic exchange of information among the riparians (del Castillo Laborde 1996, 1999). Two years later, in 1971, at the *IVth Ordinary Meeting of the Ministers of Foreign Affairs of the Parana-La Plata Basin*, the riparians signed the *Asunción Declaration*, in which they reaffirmed the validity of the principles delineated in the *Montevideo Declaration* of 1933 and in the *La Plata Treaty*. In general, subordinated to objectives of economic growth, these agreements reduced the function of water resources to ensuring the growing demand for natural resources and promoting increases in national economic efficiency (Ganoulis 2001).

2) Joint-Infrastructure Projects: Itaipú, Yacyreta and Corpus Christi

By the nineteen-seventies, multinational initiatives in the La Plata basin involved mainly the construction of hydroelectric dams. Despite existing regulatory frameworks, conflicts emerged with large waterworks. In April 1973, the heads of state of Paraguay and Brazil, Generals Stroessner and Castelo Branco, signed a bilateral agreement for the joint construction of the largest hydroelectric dam in the world, to be located on the Paraná River (Kohlhepp 1987, Elhance 1999,40-45). The signature of the Itaipú agreement ended a bitter dispute between Brazil and Paraguay over the position of the international border. By means of the new agreement, the countries also resolved the dispute over the Guairá Falls, a section of the Paraná

River that had been claimed by both countries since 1872. In 1962, the Brazilian government had militarily occupied the disputed zone, arguing that Paraguay was intentionally stalling negotiations concerning the position of the international border; Paraguay retaliated by mobilizing its own troops.¹²⁴ In 1966, a precursory treaty signed by both parties had delineated joint uses for the disputed section of the Paraná River (Betiol 1983). The construction of the Guairá-Itaipú dam would flood the controversial Guairá Falls and supply the countries with hydropower useful to their goals of economic development. The initiative was perceived as a threat by Argentina. Located upstream from the basin, the new dam had the potential to disrupt both supply of water and uses of the watershed downstream (Elhance 1999, Resende-Santos 2002). Moreover, the construction of the project would constitute a victory for Brazil, and strengthen its claim as regional hegemon (Child 1985). The Argentine government protested the signature of the Itaipú Treaty, arguing that downstream countries had not been invited to participate in the negotiations that led to the Itaipú agreement, which violated the principles of prior consultation and equality that had been established by the 1969 La Plata basin agreement and the Asunción Declaration of 1971. In retaliation, Argentina pressured Paraguay into signing a treaty for the construction of two additional dams on the basin, the Yacyretá and Corpus Christi international dams. The Yacyretá agreement was written using the Itaipú agreement as a template and responded mainly to geo-strategic and economic calculations: *“(The project is justified by) Geopolitical and geo-economic reasons, in view not only of the bi-national relations, but also of the global situation in Argentina’s North-East, which is subject to the attraction of the geo-*

¹²⁴ Geopolitical threats at the time were not just nationalistic posturing. The Itaipú accord was signed under the explicit threat of military action. In those years, Brazil got involved in the Bolivian crisis to defend Hugo Banzer and threatened to intervene in Uruguay if the Frente Amplio (a leftist party) won the elections. See: (Bandeira 1993)

economic principal development poles of Brazil, its southern and central regions. These elements oblige Argentina and Paraguay to create equilibrium points in the region, because good relations between neighbors are good relations of force. Yacyretá is necessarily in the Argentine North-East because it demonstrates that Argentina is in conditions to carry out large works with Paraguay and equilibrate the attraction of Itaipú.” (Statement by the Argentine Minister of Foreign Affairs after the signature of the Itaipú-Corpus dam to ABC-Color, Asunción, September 26th 1982, cited in Ribeiro)

The Yacyretá initiative was coupled with the project for the construction of the Corpus Christi dam (Bandeira 1993). The second dam would be located between Itaipú and Yacyretá and directly threaten the Paraguayo-Brazilian project because it could raise upstream water levels and flood Itaipú’s power-generating turbines (See Figure au-dessous).



Figure 9: Dams in the Parana-La Plata Basin

1. Yacyretá, 2. Salto Grande, 3. Itaipú, 4. Corpus Christi (projected)

Source: Adapted from Ciencia Hoy magazine;

www.ciencia-hoy.retina.ar/ln/hoy56/enfermedad.jpg (retrieved 14/06/06)

The political tensions and reciprocal threats associated with the construction of Itaipú, Yacyretá and Corpus Christi dams drove the countries into a trilateral negotiation process. This led to the signature of a new multilateral agreement over the waters of Paraná River in October 1979 (Resende-Santos 2002). The agreement regulated the maximum height of dams in the basin and reinstated the validity of existing principles and mechanisms of water governance in the basin (da Rosa 1983, Ribeiro 1994). It provided a stable framework for the management of the Paraná basin, institutionalized consultation over shared waters, and assured the “flexible operation” of the dams located in the basin.

Large infrastructure projects in the Parana-La Plata basin reflected not only a particular interpretation of the social role of the shared waters, but also the intense geopolitical competition of the riparian countries ongoing at the time. As emphasized by Ribeiro (1994), large waterworks in the La Plata basin resulted neither in the pacification of regional diplomatic relations nor in the reduction of domestic economic inequalities. The controversies surrounding competing waterworks and their political resolution are, however, indicative of the multifaceted stakes in water management negotiations. Although conflicts arose from a mix of territorial disputes, geopolitical competition and growing demand for energy, they still fostered both the establishment of multinational regulatory frameworks and of an alternative and preferred approach to deal with water management controversies. The construction of multinational and bi-national waterworks in the basin was systematically preceded by technical commissions structured according to the principles outlined in the 1933 Declaration of Montevideo, which established the equal representation of the riparian countries, independent of their respective size and economic power. The Salto Grande dam was preceded by the *Salto Grande Joint-Technical Commission*, the Itaipú dam by the *Bi-national Commission* with Brazilian and Paraguayan representatives, Yacyretá by a *Joint Technical Commission*, and the Corpus Christi dam project by the *Argentine-Paraguayan Joint Commission for the Paraná River* (Pochat, Biswas et al. 1999, Pochat, Natenzon et al. 2006). These instances of technical cooperation supplied political authorities with the scientific and technical information necessary for the implementation of the joint projects: they determined the feasibility of projects and were charged with diverse administrative responsibilities (Dourojeanni, Jouravlev et al. 2002, Pochat 2005). Even if the existence and good operation of these institutions did not necessarily indicate good relationships between the countries, the systematic creation of bi-national scientific cooperation commissions

became, over time, part of the *modus operandi* of international water governance in the region. The countries systematically implemented formal scientific and technical cooperation mechanisms before the construction of new projects.¹²⁵

C - Discovery of the Aquifer System and an Initiative for Its Management

Until the late nineteen-seventies, the projects and institutions of water management mirrored the centralization of decision-making authority at the federal level in the riparian countries, and sub-national and non-state actors were relatively marginal in decision-making processes (Dourojeanni and Cepal 1994, Dourojeanni, Jouravlev et al. 2002, Pochat 2005). During the nineteen-eighties, however, the structural changes that accompanied democratization¹²⁶ again modified the tone and the stakes attached to international cooperation in the region, as well as the actors involved in water management. Throughout the decade, democratization and new paradigms of environmental governance empowered demands in favor of the regionalization of economic development and the implementation of policies aimed at the protection of the environment. Argentina, Brazil, Paraguay and Uruguay passed new comprehensive water laws and reformed the institutional frameworks governing the resources

¹²⁵ The most notable exception to this rule led to an intense conflict between Argentina and Uruguay between 2006 and 2010. The controversy revolved around the construction of Pulp Mill factories on the Uruguayan shore, which Argentina asserted would contaminate the shared watershed and affect its tourism. The conflict was resolved in 2010, following a ruling of the International Court of Justice at the Hague. It was decided that both countries would monitor the environmental status of the river and coordinate necessary actions through the bi-national agency in charge of overseeing the Uruguay River, the *Comisión Administradora del Rio Uruguay* (CARU).

¹²⁶ Finally, after years of open and violent political conflict, local elites acknowledged that democracy could stabilize both institutional frameworks and the economy, and embraced it. Cooperation treaties signed up until the 1980s were neutral about politics, but democratization led to the inclusion of clauses in favor of the protection of the system. See : (Dabène 1997) p. 167.

(del Castillo Laborde 1996). Water governance progressively fell under the jurisdiction of new decentralized authorities, and non-state actors gained influence in policy-making processes.

The advent of democracy in the Southern Cone turned cooperation into an instrument of democratic consolidation. Civilian authorities employed international cooperation as means to reinforce their control over military forces, as the “pacification” of the international relations undermined the legitimacy of domestic calls to strengthen the military (Hurrell 1998). Democratization also paved the way for the emergence of new regional economic integration formulas during the nineteen-nineties that further stabilized and pacified regional international relations. These changes were reflected in new international cooperation agreements such as the 1986 *Treaty of Integration and Cooperation* signed by Argentina and Brazil, which led to the transformation of historical approaches to security and economic coordination (Pion-Berlin 1985, Dabène 1997, Russell and Cisneros 2000). In this context, the major differences between international water management initiatives developed during democratic as opposed to autocratic periods lay in the stakes and rationales behind the development of cooperation mechanisms, as well as in the criteria used to distribute the benefits derived from the exploitation of the resources. Cooperation was seen as an instrument of democratic consolidation, a tool for regional and local economic development, and the institutional transformations associated with democratization facilitated the entry of groundwaters into the regional political agenda. The settling of this new paradigm is cross-fertilized by international debates about environmental governance. As pointed out by Varady, Meehan and McGovern.” (2009, 153), “*the late 1970s were marked by a radical shift toward models of neoliberal governance, featuring policies such as structural adjustment programs and sharp decreases in state spending. This period was followed by a rise in the non-governmental organization (NGO) sector. Sustainable*

development, public participation, transparency, and decentralization – concepts often taken for granted in contemporary water policy – are relatively new governance paradigms, arising in the late 1980s.” New issues, such as the conservation and protection of water resources, first introduced in international debates at the 1972 Stockholm Conference of the United Nations, were reinforced at the subsequent 1977 Mar del Plata Conference, the 1992 Dublin Conference on Water and the Environment, and the 1992 Rio de Janeiro Summit. In general, these conferences mirrored new concerns in the management of water resources and provided new directions for domestic and regional policy initiatives.

1) Institutional Changes and Regional Hydrogeological Knowledge

Democratization and new international paradigms of water governance generally led to the structural reorganization of the authorities in charge of water governance in the Southern Cone. It also led to the reform of the internal statutes of domestic academic institutions. These institutions had historically been shaped by the restraints imposed by the centralization of political power in the federal governments. Governments controlled the funding and organization of public academic institutions, which meant that support for scientific disciplines in the regional universities was determined by economic development agendas and politico-strategic considerations. The governments of Argentina, Brazil, Paraguay, and Uruguay promoted scientific research on the resources of the La Plata basin for the assessment of the resources and the training of local experts, both of which were instrumental to the development of large regional waterworks (Bacolla, Pujol et al. 2005). Under this arrangement, institutions of science and technology served federal water management agencies. However, not all disciplines enjoyed equal support from the government. The study of Hydrogeology, in particular, remained subordinate to disciplines such as Geology and Hydrology. The marginality of Hydrogeological

research in the regional universities resulted not just in the limited allocation of economic resources for the study of regional groundwaters, but also in a paucity of experts and knowledge in the field.

The institutional reforms that accompanied democratization¹²⁷ created new venues for regional scientific cooperation among research institutions and the emergence of new knowledge about shared groundwater resources on a regional scale. In this sense, the history of the creation of the department of *General and Applied Hydrology* at the National University of the Littoral, in the Argentine province of Santa Fe, serves as a telling example of regional institutional dynamics. The academic department was created in 1970 in order to train qualified professionals for the evaluation, planning, and exploitation of regional water resources. The governments supported studies of Geology and Hydrology because they provided means for the governance and exploitation of water resources for economic and social development. The university failed to formally recognize Hydrogeology as a separate discipline until 1985, when the *Department of Engineering and Hydraulic Sciences* (FICH) was created (Bacolla, Pujol et al. 2005). This occurred because, prior to the reform of the university's statutes and its emancipation from the control of the federal government in the years that followed the return of democracy, the university lacked the authority to determine its own internal organization.

Democratic transitions gave regional universities the autonomy to establish new scientific disciplines, which had been forbidden under the autocratic regimes in place before. The formal recognition of Hydrogeology as independent area of scientific inquiry facilitated the

¹²⁷ There is extensive scholarship on "democratization," democratic transitions (Huntington 1991; Shin 1994; Mainwaring 1999, Mainwaring et al. 2001; Hagopian 2005). The concept denotes here the institutional transformations that generally followed the establishment of democratic regimes in Argentina (1983), Brazil (1985), Uruguay (1984) and Paraguay (1992).

development of research in the field and the emergence of new knowledge and experts on the transboundary aquifers in the region. In order to gain recognition, however, new disciplines like Hydrogeology had to demonstrate their legitimacy. Proponents of the new discipline had to carve out spaces within the regional academic institutions by demonstrating not just the epistemological validity of new claims, but also the social value of the knowledge accumulated through the practice of the discipline. Regional hydrogeologists described the process of recognition of Hydrogeology as a ‘struggle’ and emphasized the relationship between knowledge about regional aquifers and the recognition of the scientific discipline. Ofelia Tujchneider, Director of the *Hydrogeological Research Group* at the FICH and Director of the Argentine Chapter for the International Hydrogeologists Association, detailed this process: “*Groundwaters are an issue that has historically been underestimated, particularly by the technical-scientific systems of the countries of the region. In fact, all this work [the hydrogeological studies about the Guaraní Aquifer] was done without money and using weekends, spare time (...) We confronted the Academic Commission of the Argentine Geologic Association because it had trouble recognizing that hydrogeology is a scientific discipline.*” (Ofelia Tujchneider, Interview, March 30th 2006)

The emergence of Hydrogeology as an autonomous scientific discipline in the regional universities was rooted in the initiative of local hydrogeologists, who strategically mobilized to defend the legitimacy of their work and of Hydrogeology. In time, the recognition of Hydrogeology in academic institutions helped secure more funding for research. This recognition process was accompanied by the increasing international cooperation on the part of the regional hydrogeologists engaged in regional research projects.

2) The 'Discovery' of the Guaraní Aquifer System

In line with the conventions of the canonical earth sciences, the regional aquifers were historically denominated according to the name of host geologic formations (Campos 2000, Campos and Studart 2000). Before the nineteen-eighties, the principal regional aquifers were known as Botucatú and Piramboia in Brazil, Tacuarembó and Rivera in Uruguay, and Misiones in Argentina (Araújo, França et al. 1995, Campos and Studart 2000). The compartmentalization and conceptual distinction of the regional aquifers stemmed largely from technical considerations and standard practices in the field of Geology, but also demonstrated the paucity of regional-scale hydrogeological assessments (Flores Machado 2006). The limited geographical scope of hydrogeological studies was justified by both the notable physical discontinuities in the terrain and the heterogeneous behavior and occurrence of groundwaters in the region. Within Brazil alone, numerous hydrogeological discontinuities modify the occurrence and quality of groundwaters in the nation's southern states. For example, in the Ponta-Grossa section of the state of Paraná, volcanic intrusions create barriers to the flow of groundwaters, meaning that these groundwaters have limited interactions with other hydraulic systems. The management and uses of the aquifer in those areas have little impact on other sections of the aquifer system. The situation is similar in the states of Santa Catarina, Paraná and Mato Grosso do Sul where some, but not all, aquifers have high saline concentrations due to oceanic intrusion. In general, the salinity levels, the temperature of the groundwaters, and the depth of the regional aquifer vary significantly even across short distances. Accordingly, as noted by Flores-Machado, hydrogeological assessments largely focused on local specificities rather than on the regional

linkages of the aquifers.¹²⁸ In this context, the ‘discovery’ of a large aquifer system spanning across Argentina, Brazil, Uruguay and Paraguay responded neither to a novel utilization of groundwater resources in the region¹²⁹ nor to fundamental changes in the technological means available to assess the resources. Instead, it resulted from the unified denomination of the myriad of regional aquifers as a unique entity, based largely on theories suggesting the existence of linkages among the regional aquifers despite geological discontinuities.¹³⁰

¹²⁸ A representative of the Ministry of Hydraulic Resources of Uruguay stressed that “*the aquifer (...) is not an underground river, which means that its waters do not circulate in a unique direction (...) nor is [it] a large homogeneous mass (of water) under the four countries. In some places, there are barriers, which we attempt to understand by means of the technical studies.*” (Alejandro Arcelus, Interview, April 20th 2006)

¹²⁹ Jorge Rucks, the Director of the Water Management Section at the Organization of the Americas (OAS), emphasizes that despite the poor understanding of the hydrogeological features of the regional aquifers, groundwaters had been exploited at least since the nineteen-twenties: “*The aquifer’s [geologic] formation had historically been known thanks to oil prospection conducted during the 1920s, 1930s and 1940s. Oil exploration was done in the basaltic basin in Uruguay and Brazil, in the Botucatu and Tacuarembó formations. (...) In Uruguay, their exploitation began during the 1950s. (...) In Brazil, the waters are located at lesser depths; they have been used for urban supply. The first perforation in Argentina was done 10 years ago [between 1994 and 1995] at the city of Concepción del Uruguay. Thermal and touristic exploitation appeared only a few years ago.*” (Jorge Rucks, Interview, March 12th 2006)

¹³⁰ Ofelia Tujchneider stresses that: “*In 1986, we published a study in the Journal of the Argentine Geological Association. It took us some time to get it published because our approach challenged the propositions of orthodox geologists. They said that there were warm waters in this region [the Argentine side of the Uruguay River border] but that the tectonic fracture parallel to the Uruguay River had erased the sediments that make the Guarani [Aquifer, on the Argentine side of the river]. Our work proposed a different approach... We did not deny the existence of the fracture, but we did not assign dramatic consequences to it. (...) See, our structural geologists have been trained in Europe and fixated in their neurons the dramatic [geological] effect of the European Alps. Yes, the fracture exists, but its existence does not have dramatic consequences. We managed to publish this work in 1986. We proposed the existence of hot groundwaters west of the Uruguay River [in Argentina] at similar depths and temperatures than those on the east side [in Uruguay]. We established a theoretical-conceptual hydrogeological model using all the information we had available. We formulated, based on this information, a model of reality that we then had to verify.*” (Ofelia Tujchneider, Interview, March 30th 2006)

This conceptualization of the aquifer system was concomitant with the emergence of a regional network of scientists dedicated to the study of the groundwater resources, which consolidated at the same time of the transformation of the regional academic institutions.

The existence of hydraulic connections among the regional aquifers was first suggested in 1993 in the Brazilian city of Gramado, during the 10th Brazilian Symposium on Hydraulic Resources.¹³¹ The meeting was organized by the Brazilian Association of Water Resources (ABRH) and the *Instituto de Pesquisas Hidráulicas* of the Federal University of the Rio Grande do Sul state, with the support of UNESCO and other international organizations. During that meeting, a working group was organized to study the extension of the Botucatu Aquifer. The goal of the working group was to refine a hydrogeological map with regional scale, which would provide a schematic conceptual model of the system compatible with available data. In August 1994, in the city of Curitiba, the Federal University of Paraná, the Republic University of Uruguay, and the Brazilian Association of Groundwaters held a day-long meeting on *Technical and Scientific issues of the Sustainable Management of the Botucatu International Aquifer*, during which scientists confirmed the transboundary nature of the aquifer system. The initiative was supported by the Canada International Development Research Center (IDRC). In May 1996, at the *First Seminar and Workshop on the Giant Aquifer of the Mercosur*, the unified denomination was finally officially recognized. Scientists agreed on the new denomination of the

¹³¹ Jorge Santa Cruz explains that: “*The project results from a meeting, a symposium held at Gramado, Brazil. It was a Latin American conference on water resources (...) in 1992 or 1993 (...) It was organized because UNESCO presented a hydrogeological map of South America. At this meeting, following the presentation of the map, it seems a unit known as Botucatu extended beyond Brazil, into Uruguay where it had another denomination. It seemed it could also extend into Argentina and Paraguay. It was unclear because it was very deep. (...) UNESCO then fostered the idea of continuing research through a project to be developed.*” (Jorge Santa Cruz, Interview, April 20th 2006).

aquifer system, favoring *Guaraní International Aquifer* instead of Botucatu.¹³² The seminar was organized by the Universidade Federal do Paraná and was attended by scientists of Universidad de la República (Uruguay), and Universidad Nacional de La Plata (Argentina), the Argentine National Service of Health and Agro-alimentary Quality, and IRDC.

The ‘discovery’ of the Guaraní Aquifer System (GAS) was indeed unlike that of most hydrogeological formations: “[*Geologic*] formations have a name, assigned in function of their geographic position. It is a very rigorous procedure. There is a stratigraphic nomenclature code that you must respect (...) However, noticing that we were calling the same thing with different names... because of their analogous hydraulic behavior. In homage, and as a signal of unity, to speak of the same thing it was baptized *Guaraní*.” (Ofelia Tujchneider, Interview, March 30th 2006).

The non-conventional nomenclature for the regional aquifers challenged disciplinary practices, in particular those of traditional geology, as well as the historical compartmentalization of the study of natural resources in the region. The unified conceptualization of the regional aquifers reflected the instrumentality of the approach to the regional hydrogeologists. The approach was useful to the scientists because it reinforced their claims for legitimacy in academic institutions and helped procure new sources of funding for research. The discovery of the Guaraní Aquifer System resulted not just from the theorization and empirical verification of hydraulic linkages existing among regional aquifers in spite of geological discontinuities; it was also the result of the progressive consolidation of Hydrogeology in the academic institutions and the development of a regional network of experts in the field. The unified conceptualization of

¹³² Other unified denominations of the Aquifer were proposed, such as the *Giant Aquifer of the Mercosur* (Filí 1999), or *The Natural Water Spring of the Southern Cone* (Rocha 1997).

the regional aquifers mirrored the profound transformation of the relationship between the riparian countries of the La Plata basin and the processes of institutional reform that accompanied democratization during the nineteen-eighties. Moreover, the unified approach fostered the emergence of policy initiatives for the management of the resources. The regional scale of the aquifer system added strategic value to the resources: it suggested that localized groundwater management could have an impact at larger geographic scales. The scale of the aquifer system facilitated the involvement of international agencies dedicated to funding initiatives for the governance of shared water resources and the entry of localized groundwater issues into federal political agendas.

3) An Initiative for the Guaraní Aquifer System

In May 1997, a year after the regional scientists agreed on the unified denomination of the regional aquifers,¹³³ a second seminar was held in the city of Paysandú in Uruguay. On that occasion, the regional hydrogeologists drafted a public declaration, the Declaration of Paysandú, demanding the development of an institutional mechanism for the joint research, planned exploitation and preservation of the GAS. In the Declaration of Paysandú, the regional scientists expressed their willingness to politicize the issues of the GAS by requesting the creation of a regulatory framework for the governance of transboundary groundwater resources. They argued that the resolution of concrete groundwater management problems required the proper scientific assessment of the resources as well as new regulatory frameworks. The regional scientists reached out to political authorities in the host countries and to international organizations. They sought funding for hydrogeological research, but also the recognition of groundwater problems.

¹³³ The unified denomination did not include all the aquifers in the region. It was limited to those with hydraulic connections with other regional aquifers.

This acknowledgement of groundwater issues highlighted the social role played by hydrogeology studies. It validated the work that had been conducted since the nineteen-eighties with limited institutional support. Therefore, international funding promoted not just the development of Hydrogeological studies in the region, but also the empowerment of local level actors in their demands for political responses at the federal level.

During the Paysandú meeting, the scientists also decided to draft an international research project intended to improve the hydrogeological map of the region. The project was submitted to UNESCO, the OAS, and the Global Environment Facility (GEF) of the World Bank for funding (Campos 1999, 2000). The research proposal prepared by the regional scientists was received and reformulated by officials of the GEF.¹³⁴ Jorge Rucks, the Director of the Water Management Section at the Organization of the Americas (OAS) further details that the GEF: *“Responded to the universities that they would not finance a project solely for research, because it is not the GEF’s mandate. (...) They would, however, finance the government’s initiative for the management, which would need information coming from research. Then, if the countries and universities joined forces in the construction of the project, they could come up with a project*

¹³⁴ Established in 1991, the GEF is an independent entity that was created through a partnership between the UN Programmes for the Environment (UNEP), Development (UNDP) and the World Bank (Chatterjee, Zoe Young). It is, since the Rio Summit of 1992, the largest international organization exclusively dedicated to environmental issues and the principal source of funding in this area for developing countries (Bowles; Sjoberg). One of its main goals is the resolution of conflicts and the development of international cooperation for the management of international waters (Gerlak). It is a “facilitating” agency dedicated to the implementation and adoption of international law about water resources, and the development of regional agreements and action strategies for environmental protection (GEF 2001). Although GEF’s international waters focal area does not serve as a financial mechanism for any specific convention, it is associated with many global and regional conventions that are involved in transboundary water systems, mostly at a regional level (GEF 1996).

with a component aimed at the research of the resources, and another for the management.
(Jorge Rucks, Interview, March 12th 2006).

The representatives from the World Bank envisioned a cooperative project that would foster the joint governance of the shared groundwater resources between Argentina, Brazil, Paraguay, and Uruguay. The initiative hinged however on support from officials in the host countries. A team of representatives from the international organization thus approached the political authorities of Argentina, Brazil, Paraguay, and Uruguay in order to evaluate their interest in developing a multinational governance framework to deal with the resources of the Guaraní Aquifer System. Dr. Tujchneider stresses that: *“The GEF people saw an interesting opportunity, and in 1999 they came over to know the aquifer better. How did they make it? Through here: the Littoral University, September 21st 1999. (...) a group of people from the World Bank came to see what the Guaraní Aquifer was about. In our conference room, and in the presence of the University’s authorities, the director of our group made a presentation (...) From here they went to Buenos Aires to meet representatives from the national agencies, the Ministry of Foreign Relations and others. They did the same thing in the other countries.”*
(Ofelia Tujchneider, Interview, March 30th 2006)

Following the visit from the GEF representatives, government officials in the agencies of water management and foreign affairs recommended the creation of a country-level inter-ministerial committee, charged with steering the cooperation initiative (SGSAG 2005). The riparian countries negotiated the establishment of an institutional structure adapted to deal with both the scientific and political aspects of groundwater management. In line with the recommendations of the GEF, the preferences of the local scientists, as well as with the

traditional approach to the management of shared water resources in the region, the countries favored the establishment of a preliminary technical cooperation mechanism for the identification of transboundary groundwater management priorities. The countries established an intergovernmental council in charge of the political and strategic steering of the project following the equality principle first outlined in 1933. The equality principle was maintained for the operational steering of the project.

The approach ensured that the cooperation process would remain under the direct supervision and control of the countries—which meant sovereignty would not be threatened (Krishna and Salman 1999). Although the technical cooperation initiative resembled that of previous joint water management experiences in the region, the process that led to its inception resulted from the empowerment of new actors in the policy-making process, international organizations and decentralized political actors. In fact, the approach favored by the countries was compatible with the preferences of the GEF, which holds that the consensual understanding and collaborative identification of scientific information fosters consensual solutions to shared problems and bolsters the effectiveness of the policies resulting from cooperation (Bowles and Prickett 1994, Gerlak 2004). Although the final structure of the cooperation initiative designed to set the foundation for the co-management of the Guaraní Aquifer System reflected the preferences of the federal governments, it was nonetheless also conditioned by the funding rules of the GEF and the World Bank.

In 2002, GEF representatives stressed that “*without this GEF-financed project, it is highly likely that the countries would not take measures at this stage to protect the transboundary water resources of the Guaraní aquifer system*” (IW:Learn 2002, 5). They suggested that the

exploitation of groundwater resources at the national and sub-national levels would most likely continue to increase to the point where the reversal of negative effects would be difficult and costly. They emphasized that because “*an international legal framework for the management of transboundary groundwater resources currently does not exist [...] the World Bank, through the GEF, could make a significant contribution to shaping an institutional framework regarding transboundary groundwaters that could serve as a replicable model in other countries and regions*” (p. 10). The organization saw the project as a means both to fulfill a substantive environmental objective and to support the development of joint groundwater governance frameworks.

D - The Formalization of the Groundwater Management Initiative

The allocation of the funds necessary for the implementation of the *Project for the Protection and Sustainable Development of the Guaraní Aquifer System* (GASP) was approved by the GEF in July 2002. The World Bank was designated as the “implementing agency” and the Organization of American States (OAS) was charged with overseeing the execution of the funds allocated to the project. In practice, both organizations were charged with the supervision of the execution of the funds allocated to the project, but in different roles: the Bank provided general fiduciary oversight, while the OAS served as a financial and human resources manager with local representation. The total cost of the project was estimated at \$26.8 million, of which \$13.4 million would be fronted by the GEF, \$12 million by the riparian countries, and the rest by other international donors.

Implemented in 2003, the project aimed to: 1. increase the available stock of scientific knowledge about the GAS; 2. establish a permanent monitoring system for the groundwater

resources; 3. create a Transboundary Diagnostic Analysis and a Strategic Action Plan, aimed at the identification of governance priorities and appropriate responses to the problems; and 4. identify the basic guidelines for a future formal and stable framework for the integrated management of the resources rooted in existing water policies and management instruments (SGASP). Under the provisions of the project, the OAS signed contracts with the World Bank and with each of the four countries, and created a Technical Secretariat. In practice, the relations between the intergovernmental steering committee, the “Superior Council,” the Technical Secretariat, and the GEF were orchestrated by the OAS through its satellite office in the city of Buenos Aires.

1) The Implementation of a Cooperation Project

Installed in Montevideo at the Mercosur headquarters, the Technical Secretariat was charged with the coordination and supervision of the consultants hired to execute the different aspects of the project. It functioned as the operational center of the cooperation initiative, charged with the implementation of strategic decisions, the execution of the funds according to international standards and requirements, and ensuring that research was conducted properly and that it led to specific governance recommendations. The Secretariat was also in charge of the management of two specific projects: the Universities’ Fund and the Citizens’ Funds, which financed local scientific research projects and public outreach initiatives.

The Secretariat was organized into six sub-sections. The first sub-section was in charge of the “expansion and consolidation of the scientific and technical knowledge about the Guaraní Aquifer system,” which included gathering the factual data necessary for the development of

“consensual and effective” protection and management of the aquifer system.¹³⁵ The second sub-section was aimed at the development of a joint management framework according to the Strategic Action Program, which was the core mandate of the project. This sub-section drew from scientific, technical, institutional and legal knowledge for the development of principles and concrete tools dedicated to the sustainable management of the GAS.¹³⁶ The third sub-section focused on the participation of non-governmental stakeholders, social communication and environmental education. It addressed the need both to communicate the GASP’s objectives, increasing social awareness about the existence of the regional groundwaters, and to process feedback from civil society.¹³⁷ The fourth sub-section was charged with the evaluation of the project’s output and the diffusion of its results. It ensured the operation of the GASP according to international operational standards. The fifth sub-section was dedicated to the development of specific groundwater management policies for the mitigation of environmental deterioration. It

¹³⁵ They included: 1. Studies for the consolidation and expansion of the scientific knowledge base about the geometry, structure and hydro-dynamic of the aquifer system—in particular, through the determination of the boundaries of the system in its southern and occidental sections and the development of an inventory of the public and private wells to be used for the assessment of water quality and its uses—and 2. The technical and socio-economic evaluations of current and future uses of the groundwaters, through the analysis of the available technologies available for the extraction and exploitation of the resources.

¹³⁶ In order to achieve its goals, the sub-section was subdivided in four sub-sub-sections: 1. Installation and maintenance of a monitoring network for the GAS, a network that would survey at least 5% of the GAS wells; 2. Design and installation of a system of information for the GAS dedicated to the management, normalization, diffusion and use of data gathered from the monitoring network. This component would support management decision-making, 3. Development of a strategic plan for the coordinated management of the aquifer system; and 4. Institutionalization for the sustainable use of the scientific information, for its dissemination to local users, and for capacity-building.

¹³⁷ Stakeholders included the water users, agencies responsible for regional water management, water utilities, NGOs, research institutions, and the media. This component prepared: 1. A regional plan for the information and participation of the public, supported by a Manual of Social Communication about the project; 2. A “Citizen’s Fund” for the development of practical initiatives for the reinforcement of environmental education; and 3. A strategy to properly deal with the practices of aboriginal populations and address their idiosyncratic mechanisms of water governance.

focused on the application of new knowledge about the GAS, for the evaluation of local groundwater exploitation practices and for the identification of approaches to the use of the resources at the local level. The sixth and final sub-section of the project was dedicated to administrative support. It dealt with the bureaucratic implementation of political decisions stemming from the Superior Council and administrative tasks that ensured compliance with the rules of the funding agencies.

The GASP concentrated its activities in four “hotspots.” These areas denoted sections of the aquifer system in which groundwater governance seemed most necessary and urgent for the sustainable management of the resources. They were located in sections of the aquifer in which the resources were considered at risk, and which could provide experiences for use in other sections of the aquifer. Each hotspot dealt with different issues of groundwater management: transboundary impacts, the contamination of the resources, and overdraft of the resources. The Hotspots, which were also known as Pilot Projects, included the cities of Concordia-Salto (Argentina-Uruguay), Rivera-Santana do Livramento (Uruguay-Brazil), Itapúa (Paraguay), and Riberão Preto (Brazil). Issues revolved around the impact of competitive exploitation in a deep confined section, the protection of areas of recharge in a non-confined section of the aquifer, the mitigation of the eco-systemic deterioration triggered by groundwater exploitation, and the problems triggered by the use of the resources for urban supply.

2) Political Challenges to the Project

At the onset of the project and throughout its implementation, several groups contested the protagonism of the international organizations in the multi-lateral initiative. Organizations such as the *Centro de Militares para la Democracia Argentina* (CEMIDA) argued that the

international organizations' goal was to assess the strategic natural resources in the region and to privatize the exploitation and ownership of the regional groundwaters (Bruzzone 2004). These critics framed the challenges of transboundary groundwater management in terms analogous to those historically associated with surface waters and pointed to the risks posed by the participation of international organizations in the development of rules for the governance of transboundary groundwaters (Eissa, Domínguez et al. 2001). A more interesting criticism not explicitly voiced by these organizations but posed by regional scientists pointed to the impact of the conditions imposed by the funding rules of the GEF and the World Bank. Regional scientists noted that the funding rules of the international organizations were embedded with principles detrimental to the regional governance of the resources in the long-term. Dr. Jorge Santa Cruz, Scientific Expert at the Secretariat, notes that: *“The bank couldn't employ public institutions in projects such as this one because it already had ongoing institutional development projects (...) The principle adopted from day one was that the universities would not be intervening directly.”* (Jorge Santa Cruz, Interview, April 20th 2006).

In fact, instead of directly involving the regional universities for the completion of the regional hydrogeological assessment, the internal rules of the GEF required open bids for the hiring of the international consultants charged with hydrogeological research. The funding rules forbade the allocation of resources to public agencies.¹³⁸ The problem arises from the fact that regional universities have historically served as a source of expertise for the implementation of water governance policies in the region and are integrated in the decision-making processes. Their alienation from the development of the GASP creates a long-term problem because after

¹³⁸ This rule, designed to insulate the GEF (to some degree) from cronyism and graft, perversely operated against local capacity-building.

the international funding is depleted, these institutions will remain the critical source of expertise for the development of policies for the local governance of the resources. The direct implication of the universities would have likely contributed to the greater awareness and effectiveness of the initiative in the long term. Recognizing this issue, the countries implemented different strategies in order to include local and regional scientists and scientific institutions in the project.¹³⁹ Although the influx of funds for regional hydrogeological research failed to directly reach the academic institutions, the local scientists were involved in the initiative.

3) New Institutions and Management Policies derived from the Project

Despite the criticisms, in line with its original intent, the GASP established the bases for the development of regional groundwater management policies. The project led to a Strategic Action Plan (OEA 2009) rooted in the knowledge of the resources and new policy coordination mechanisms. The plan reflected the outcomes of the project: the survey and geo-reference of existing water-wells, detailed hydrogeological assessments and maps of the region, hydrodynamic models of the aquifer system, and a piezometric monitoring system in identified critical hotspots. This information was centralized in a system of geographic information (SISAG) publicly accessible and made available for the decision-making at the federal, regional, and local levels. The project facilitated the establishment of a stable mechanism for the exchange of information about the aquifer among stakeholders, which was instrumental for the

¹³⁹ Jorge Santa Cruz explains that “during the call for bids, in particular those concerning hydrogeology, which was one of the most complex (...) we demanded that all firms, or group of firms, needed to have a local partner. At least one per country. This was very successful and permitted the engagement of local professionals of the technical and scientific system through local businesses. That was the only place where they could find suitable specialists. I do not know the exact percentage, but some 70 or 80 percent, which is the immense majority of the researchers and consultants currently working for bidders are university professors. They belong to the universities and to the technico-scientific system.” (Jorge Santa Cruz, Interview, April 20th 2006)

development of concrete management actions. Moreover, the countries developed several specific local-level operational arrangements, based on the mutually recognized scientific data gathered by the project. The official scientific joint assessment simplified the common framing of groundwater problems and policy-making at the local level.¹⁴⁰

The countries introduced groundwater into their agendas and coordinated policies for its management. Hydrogeologic information helped reframe geopolitical concerns and supported the creation and implementation of local-level solutions for the management of the transboundary aquifer. Research derived from the project showed, for example, that the aquifer's general lateral flow of water is naturally slow, as dictated by the hydraulic gradient, and that it significantly accelerates only with human intervention at the local level (Tujchneider, Perez et al. 2007, Cox, Olson et al. 2009, 2009). As a result, the cities of Concordia and Salto agreed upon common regulation of drilling practices, waste disposal and the establishment of minimum distances between wells. The city of Riberão Preto began independently regulating groundwater abstraction and the protection of the aquifer's local recharge zones.

Moreover, the project paved the way for the signature of a formal agreement exclusively dedicated to the management of the aquifer system (Amore 2011). The first of its kind, the agreement signed in 2010 was developed according to the principles delineated in the draft articles of the Convention on the Laws of Transboundary Aquifers, a document presented to the UN General Assembly in 2008, and sent for ratification to the member countries in 2011 (Sindico 2011). In this sense, the policies and management mechanisms developed for the GAS are not just an example of cooperation in the co-management of transboundary groundwater

¹⁴⁰ It also helped dispel ill-informed assumptions about the aquifer's features that, paradoxically, had initially mobilized the countries to undertake further research about the transboundary aquifer.

resources, but also a model for the institutional framework necessary for the management of these resources at the global level.

E - Conclusion: Formal and Informal Mechanisms for Governance

This chapter focused on the role of actors and institutions dedicated to scientific knowledge production in the development of policies for the Guaraní Aquifer System. It described the factors and strategic rationales that were subjacent to the discovery of the transboundary aquifer system, and their effects on the ultimate approach chosen for the management of the shared resources. In this respect, this approach differentiates itself from other studies of the Guaraní Aquifer System, which examine the accumulation of scientific knowledge about the resource or the content of the regulatory instruments created for its governance; it reviewed instead the specific institutional and political processes that fostered the conceptualization of the regional groundwaters as a unified aquifer system and its consequences on the political process.

Historically, the water resources shared by the riparian countries of the Río de La Plata Basin were proxies of the geopolitical competition existing between the countries. The States saw the waters of the shared basin as means to fulfill their economic development plans and demarcate their sovereign spaces. Scientific research dedicated to the study of shared water resources was nationally compartmentalized and shaped by the respective governments at the national level. The vast majority of academic institutions were funded and organized by the State, and the formal recognition of scientific disciplines in regional universities depended directly on the decisions of the national Ministries of Education. The academic departments in the regional universities located along the La Plata basin were funded and organized for the training of experts and the production of the knowledge deemed necessary for the construction and maintenance of large infrastructure projects in the area—and not all scientific disciplines received equal official support. Hydrogeology studies were, in particular, considered subordinate to other canonical disciplines such as Hydrology and Geology, and were allocated fewer

economic and institutional resources. Consequently, the region lacked experts and studies in the field. During the nineteen-eighties, however, regional democratization and the subsequent autonomization of academic institutions from the federal governments facilitated the emancipation of Hydrogeology from other scientific disciplines, which fuelled the significant increase in the number of hydrogeology experts and the study of the region's aquifers and groundwater resources.

The discovery of the Guaraní Aquifer System reflected not just the theorization and empirical verification of hydrologic connections between local aquifers, despite regional geological discontinuities; it also denoted the consolidation of Hydrogeology in the regional academic institutions and the establishment of new expert networks. In this sense, the conceptualization of the Guaraní Aquifer System resulted from the strategic action of the regional hydrogeologists. In fact, the suggestion that the regional aquifers – which had been, until then, largely studied and conceptualized as separate entities – should be considered as part of a transboundary aquifer system was instrumental to the regional hydrogeologists' ongoing struggle for recognition and resources within regional academic institutions. The scale and consequent geostrategic importance of the transboundary aquifer helped capture new economic resources from international agencies dedicated to funding research about shared natural resources and hydrogeology's claim for recognition on scientific and social bases.

Scientific research on regional groundwater resources was accompanied by explicit calls for political action. The scientific conceptualization of the Guaraní Aquifer System prompted the involvement of public officials concerned with the strategic nature of the resources. The politicization of the Guaraní Aquifer System – supported by the regional scientists, but reflective

of the strategic interest of the national governments – led to a process of international political cooperation involving Argentina, Brazil, Paraguay, and Uruguay. In 2000, the four countries, co-financed by the Global Environment Facility, launched a project aimed at further study of the Guaraní Aquifer System. The initiative produced a knowledge base for the development of policies for the protection and sustainable management of the aquifer system. Concluded in 2009, the international research project produced a strategic action plan, which facilitated the development of concrete management policies at the local, regional and national levels. In 2010, the governance mechanisms of the Guaraní Aquifer System were further reinforced through the signature of a multi-lateral framework agreement.

The process that led to the creation of the governance instruments for the management and sustainable exploitation of the Guaraní Aquifer System is indicative of the many political roles of ideational factors in environmental governance. Information about hydrogeology shaped the cognitive framework according to which political actors formulated their preferences. It was simultaneously instrumental to its introduction in the political agenda and critical in the political negotiation of concrete management provisions. Moreover, in the case of the Guaraní Aquifer System, theories about the aquifer system's geographical scale and denomination were not independent from the struggles for disciplinary emancipation and legitimatization. The discovery and politicization of the GAS reflected the reform of regional academic institutions. The strategic conceptualization of the Guaraní Aquifer System was articulated into a political process through the interaction of the regional hydrologists with the States and international organizations. The approach operated as a tool for the legitimatization of the scientific discipline, as well as for driving international political dialogue about the use of shared resources.

The historical regional paradigms of water management favored competition over the shared resources according to geopolitical concerns. These paradigms were crystallized as much in policies and institutions as in experiences of political interaction. Although official negotiations about the “new” shared resources—the waters stored in the Guaraní Aquifer System—did not lead to significantly original forms of international political interaction, they did originate in the mobilization and interest of actors who were historically marginalized in decision-making. In fact, although intergovernmental cooperation and co-management of the shared water resources of the Río de la Plata basin and those of the Guaraní Aquifer System are *a priori* similar, they resulted from very different political processes. Instead of being designed and directed exclusively according to the preferences of State agents, the governance of the aquifer system was fostered by subsidiary political authorities and non-state actors: expert networks and international organizations.

The development of a formal agreement and local level policies for the transboundary aquifer system reflected the recognition of the potential and existing problems attached to the resources, and the emergence of new subsidiary political actors interested in their resolution. The implementation of management mechanisms resulted from the transformation of both systemic factors, in particular the paradigms of regional cooperation and water governance, and the empowerment of regional actors in favor of the development of a formal framework for the international management of the resources.

VIII - Conclusion: The Problems and the Management of Transboundary Groundwater Resources

This research project was driven by two main objectives: 1. to explain the historical indifference towards transboundary groundwater resources in international discussions and policy-arrangements, and 2. to identify the factors determining the nature of management mechanisms employed to govern them. In other terms, this work sought to pinpoint the factors determining the entry of problems associated with transboundary groundwater resources into the political agenda, as well as those that shape the implementation of coordinated or unilateral approaches to the management of the resources. In line with these general goals, Chapters One and Two reviewed basic concepts about the resources and the recognition of ‘groundwater problems’ as well as the literature dedicated to the emergence of regulatory frameworks for water resources. Based on these contributions, Chapter Three outlined a strategy for the use of ideational and cognitive factors as an Ariadne’s thread to navigate the maze of theoretical contributions of water management, and to structure the analysis of empirical cases. Finally, Chapters Four through Seven examined three cases of transboundary groundwater management. The cases of the Guaraní Aquifer System, the Génévois Aquifer, and the Mesilla and Hueco-Bolsón Aquifer were selected because, in addition to offering the “most-different” positive expressions of transboundary water management, they also highlighted significant commonalities in the process leading to the recognition of groundwater problems, and in the factors determining management decisions.

Conventional theories about the emergence of international environmental regimes argue that the mechanisms for the management of water resources are functional to the resolution of existing and potential conflicts and, depending on the analytical scope, are either the expression

of the preferences of powerful States or the outcome of political bargaining processes. The emergence of formal agreements for the management of water resources is usually presented as a response to the threats associated with the resources, depending on the relative power and preferences of stakeholders. Research dedicated to water management generally highlights the factors behind conflict and cooperation over the resources, as well as the effect of institutional frameworks on processes of strategic decision-making. The literature encompasses power-based state-centric theories alongside fine-grained empirical analyses of the institutions and politics that shape the creation, implementation and effectiveness of water management mechanisms at different levels of governance. However, research about water regimes seldom treats the factors that shape the emergence and content of the institutions of water management. Moreover, only a fraction of the extensive scholarship about the management of shared waters deals with groundwaters. In light of the ongoing debates about the relative absence of regulatory frameworks for the management of transboundary groundwater resources at the global level and the role of institutions and power in environmental governance, this research focused on ideational factors which, although often missed or implicit in the mainstream literature, are constitutive of the emergence of governance mechanisms dedicated to these resources.

In the case of the G n vois Aquifer, the city of Geneva progressively increased its reliance on groundwater resources over the course of the twentieth century. The process was largely driven by the relatively low cost of the tapping the regional aquifer, as compared to alternative sources of freshwater. Groundwater resources became instrumental to the development of water-scarce areas of the region; the resources served both as a new source of freshwater and as a cost-competitive safeguard to the potential contamination of regional surface waters. The understanding of regional hydrogeology grew concomitant with the development of water

infrastructure in the region and the training of experts in the field responsible for water management decisions. Hydrogeological knowledge revealed that the intensive pumping of the aquifer by the regional water utilities was progressively depleting the G n vois Aquifer. The better understanding of the resources –along with new technological improvements– also demonstrated that the city of Geneva could potentially recharge the aquifer to restore the water table at a competitive cost, and depending on the volume of recharge, negate French access to the resources. This information simplified the negotiation of a joint management agreement between stakeholders in Geneva and the neighboring French towns, effectively operating as a power resource for the Swiss in the context of bilateral negotiations. Reciprocally, the lack of an economically competitive alternative encouraged the French authorities to cooperate and participate in the recharge of the G n vois Aquifer. The coordinated management approach was enacted in a formal binding agreement. Although its legal legitimacy was relatively dubious before the devolution of environmental governance authority to subsidiary powers during the nineteen-eighties, the mechanism facilitated the implementation of the coordinated actions necessary to mitigate the most pressing problems related to the G n vois Aquifer in a sustainable fashion.

In the Paso del Norte region, reliance on groundwater resources was largely due to the extreme aridity of the region and intense competition over the limited regional surface waters. The use of the resources made possible significant regional economic and demographic growth in the otherwise water-scarce region. Knowledge about groundwaters accumulated throughout the twentieth century, driven principally by experts and academic institutions located in the U.S., but also involving collaboration with counterparts in Mexico. However, despite the relatively early availability of fundamental models of the regional hydrogeological conditions, scientific

cooperation in the field was hindered by bilateral political distrust. This was due to the political tensions that arose during the Cold War between the countries and the increasing competition over shared water resources. Nevertheless, the intensive exploitation of the resources triggered the noticeable quantitative and qualitative decline of the groundwater stored in the two major local aquifers, the Hueco and Mesilla Bolsón aquifers, prompting the action of water managers. The local experiences of surface water management translated into diverse water laws and a complex institutional framework, which led to the framing of joint management initiatives as being risky for those with a stake in the maintenance of ongoing groundwater exploitation patterns. Nonetheless, the common nature of groundwater problems facilitated the emergence of informal dialogues at the local level, which were aimed at the exchange of basic information deemed necessary for strategic decision-making by the local water utilities. The information derived from these exchanges supported the implementation of actions for the mitigation of groundwater problems on both sides of the border, as well as the easement of political tensions. Although mitigating actions have proved relatively effective in the mitigation of groundwater problems, the Hueco and Mesilla Bolsón aquifers continue to be exploited unilaterally according to the preferences of users and regulatory frameworks in Mexico and in the United States.

In the case of the Guaraní Aquifer System, the recognition of groundwater resources resulted from the reform of regional academic institutions that followed the processes of institutional decentralization and democratization of the nineteen-eighties. The Guaraní Aquifer System was driven into the political agenda by the interaction of the regional hydrologists with state agents and international organizations. The theorization and empirical verification of hydrologic connections between regional aquifers occurring beneath Argentina, Brazil, Paraguay, and Uruguay denoted the progressive consolidation of Hydrogeology in the regional

academic institutions and the establishment of new expert networks in the region. The scale and apparent geostrategic importance of the aquifer system helped capture economic resources from international agencies dedicated to funding research about shared natural resources and fostered calls for political action. Despite the fragmented and generally limited impact of groundwater problems, public officials at the national level became concerned with the strategic nature of the resources. The identification of the specific problems associated with the resources resulted from a multi-level process of political cooperation, which led to the development of specific unilateral and internationally coordinated policies for the protection and sustainable management of different sections of the aquifer system. Management mechanisms included concrete internationally harmonized local level management policies –formally and informally coordinated norms for groundwater exploitation– as well as a multi-lateral framework agreement specifying the general principles for the coordinated management of the shared resources.

In the three cases, the recognition of groundwater problems was driven by the interplay of particular groundwater exploitation patterns, the increased understanding of the factors behind hydrogeological conditions, and the changing social value attributed to the services provided by the resources. None of these factors, taken individually, was sufficient to explain the entry of groundwater problems in the political agenda. Reliance on groundwaters increased the value of the services provided by the resources, albeit only given a 'sufficient' understanding of the factors behind the deterioration or depletion of the resources. Simultaneously, the value of groundwater resources was shaped by the availability of hydrogeological information and modeling techniques because it both exposed the causes of groundwater degradation, and determined the stakeholder's ability to exploit and to manage groundwater resources. The interactions of these three factors highlight the social nature of groundwater problems, meaning that the qualitative

and quantitative deterioration of the resources only became worthy of public attention when intractable environmental challenges were both attached to specific stakes and turned into potentially solvable problems. Moreover, the nature of groundwater problems changed over time –with new interpretations of the meaning of groundwater deterioration and the emergence of new interests attached to the fate of the resources.

The processes of social construction that lead to the recognition of groundwater problems are too often ignored by the literature dedicated to water management. Problems tend to be taken for granted –seen as existing a priori of the policy-making process– or, alternatively, framed as purely instrumental to the strategic preferences of political actors. In this sense, perhaps the most significant contribution of the constructivist approach employed here in the analysis of the cases is that it highlights a constitutive phase of the policy-process. The formulation of groundwater problems is concomitant with the constitutions of the relevant stakeholders advocating for and resisting the emergence of groundwater management mechanisms. This analytical approach emphasizes that the recognition of groundwater problems is concomitant with the formulation of preferences vis-à-vis the management of the resource; in other words, the acknowledgement of groundwater problems is inseparable from the involvement of actors in the political process and from the entry of the resources in the political agenda. This is a process driven not just by ‘objective facts,’ but also by the changing meaning of these facts in specific socio-historical contexts.

The acknowledgement of the role of the social and of ideas in the recognition of groundwater problems should not be confused with a post-modern critique of the conventional theories of water management. Mainstream theoretical approaches are rooted in ideational and

cognitive factors, albeit usually implicitly. Drawing from this observation, the analytical framework integrated existing theories, and explored their potential explanatory power to transboundary groundwaters. It found no fundamental contradiction other than methodological and analytical preferences between theories of 'regimes' and theories of 'governance.' On the contrary, applied to the cases, the analytical framework demonstrates that while the recognition of the resources is a critical first step in the development of actions for the mitigation of their quantitative and qualitative deterioration, the implementation of different management strategies is ultimately, and simultaneously, dependent on systemic and socio-institutional factors.

The understanding of transboundary aquifers and the social recognition of groundwater problems does not warrant the emergence of any particular type of management mechanism. Management approaches are shaped as much by the nature of the problems as by power asymmetries, established institutional frameworks, and the entrepreneurship and dialogues of political actors. Still, in all three cases, the emergence of initiatives for the management of transboundary groundwater resources accompanied the process of recognition of groundwater deterioration as a problem: the recognition of groundwater problems simply proved to be empirically inseparable from the formulation of management strategies. In the case of the G n vois, the political responses to the problems of the aquifer reflected the power asymmetries existing between the parties at the regional level, as well as the engagement of local level water managers interested in the prompt resolution of the problems associated with the shared resources. In the case of the Guarani, information about hydrogeology was simultaneously instrumental to the introduction of groundwaters in the political agenda and the delineation of concrete management provisions, but it was also an instrument for the strategic empowerment of local networks. Finally, in the case of El Paso del Norte, despite the clear understanding of the

challenges imposed on the aquifer by exploitation practices, geopolitical differences and local level preferences systematically conspired against the coordinated management of the resources.

Finally, the cases highlighted the fact that although the emergence of scientific knowledge about the resources was not purely driven by political agendas, political actors were well aware of the implications of new knowledge about the shared resources on management decisions and international negotiations. The influence of new knowledge about the resources depended on whether science and expertise about transboundary groundwaters was seen as ‘objective knowledge’ or as ‘contested information’ (Stone 2002). Contested knowledge about groundwaters resulted from situations in which it challenged established institutional and regulatory frameworks. This is because established institutional frameworks echo particular interpretations of policy-problems. As such, they provide standards of legitimacy for new knowledge and for alternative framings of environmental problems. In fact, the legacy of water management institutions shapes not just the possibilities of political intervention; it also configures forms of interaction between actors involved in the production of knowledge and in decision-making.

This research suggests that there is no unique approach to the management of groundwater resources, only contextually appropriate regulatory mechanisms in response to prevailing interpretations of the challenges and specific threats posed by the resources. In fact, no single governance approach can ensure the definitive resolution of transboundary groundwater problems. This is simply because groundwater problems are a constantly moving target; they will inexorably shift with new uses of the resources, knowledge about them, and the social valuation of the services they provide. However, if transboundary groundwater management must embody

mechanisms to adapt to new information, technical capability, and social values, in application, no simple or uniform ground water governance template can be ever be durable.

Transboundary groundwater governance is a recursive process: a dynamic and contentious exchange between multi-level institutions that reflect previous agreements over the sources of legitimate knowledge and State interests. The process is grounded on and fuelled by constructed meanings, embedded in institutional frameworks and the strategic rationale of the actors. Norms and principles of groundwater governance, however, do not result from the simple debate of preferences. Instead, ideas also have agency as well as a reciprocal effect on ongoing domestic processes. International debates and norm-making initiatives catalyze the development of new domestic groundwater management initiatives through both material and symbolic linkages.

Further research about the management of transboundary groundwater resources needs to address several questions that escaped the scope of this work. To what extent are the factors shaping the emergence of groundwater management mechanisms relevant to other natural resources? What are, if any, the particularities of water vis-à-vis other natural resources? The literature dedicated to the analysis of environmental governance will need to tackle both micro and macro drivers, as means to improve the actionability of research and to refine the effectiveness of management mechanisms. Knowledge and understanding of the factors that shape environmental management must break free from sectoral and disciplinary constrictions. Practitioners and other actors involved in the daily governance on the resources are in need of means of actionable information about the factors that determine both political preferences and the outcome of policy-negotiations. Moreover, future assessments should consider the application of the analytical framework suggested for groundwaters to other natural resources,

but also challenge its tenets. Another question, perhaps more critical, is: what are the consequences associated with different governance approaches? Whether the management of the resources is coordinated or unilateral has a significant impact on the relations of the stakeholders and on the uses of the resources. This research suggests that different approaches may be equally functional for the resolution of transboundary groundwater problems, but it fails to consider the effect of these approaches on institutional mechanisms, and in the relations of the countries sharing the resources.

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X - Appendix: Transcribed Interviews

Interviewee¹	Function	Date	Location
Alejandro Arcelus	National Coordinator of the Execution Unit of the GASP in Uruguay. Officer of the National Hydrographic Direction of the Ministry of Transport and Public Works.	April 20th 2006	Montevideo, República Oriental del Uruguay
Enrique Massa	Facilitator Concordia-Salto Hotspot. GASP	March 29th 2006	Concordia, Argentina
Gonzalo Entenza	Diplomat. Operational officer at the Ministry of Foreign Affairs overseeing the implementation of the GASP	March 16th 2006	Buenos Aires, Argentina
Jorge Rucks	Director of the Water Management Section at OAS	March 12th 2006	Buenos Aires, Argentina
Jorge Santa Cruz	Technical Coordination Officer. GASP.	April 20th 2006	Montevideo, República Oriental del Uruguay
Luís Amore	Secretary General GASP	April 18th 2006	Montevideo, República Oriental del Uruguay
María Esther Bondanza	Ambassador. Environmental Affairs Section	March 16th 2006	Buenos Aires, Argentina
Miguel Fernández	Public Planner for the Municipality of Concordia. Representative at the Binational Commission for the support of the GASP	April 29th 2006	Concordia, Argentina
Ofelia Tujchneider	Director of the Hydrogeological Research Group/Directeur at the Facultad de Ciencias Hidricas of the Universidad Nacional del Litoral, Argentina.	March 30th 2006	Santa Fé, Argentina
Roberto Montes	Communications Officer. GASP	April 20th 2006	Montevideo, República Oriental del Uruguay
Silvia Rafaelli	Under-Secretariat of Water Ressources. Argentina	April 25th 2006	Buenos Aires, Argentina
Claudio	Under-Secretariat of Water Ressources. Argentina	April 25th 2006	Buenos Aires, Argentina

¹ Full transcribed interviews are available in CD format.

Laboranti			
Alice Aureli	Director of UNESCO's International Hydrological Programme	January 26th 2010	Paris, France
Alfredo Granados Olivas	Hydrogeologist for the Universidad Autónoma de Juárez	February 27th 2010	Ciudad Juárez, Chihuahua
Roberto Salmon Castelo	Principal Engineer. Comisión Internacional de Limites y Aguas.	February 27th 2010	Ciudad Juárez, Chihuahua
Antonio Rascón	Commissionner. Comisión Internacional de Limites y Aguas.	March 9th 2010	Ciudad Juárez, Chihuahua
Christopher Brown	Geographer at the New Mexico State University	March 11th 2010	Rio Rico, AZ
Claudia Campero	Environmental Activist	February 22h 2010	Mexico City
Christina Leb	Lawyer, Graduate student at the Plateforme de Droit International sur l' Eau (Université de Genève)	March 16th 2010	Genève , Switzerland
Carlos Rincón	EPA Field Officer	February 27th 2010	El Paso, TX
Christopher Scott	Political Scientist. Director of the Udall Center, University of Arizona	March 16th 2010	Tucson, AZ
Elaine Hebard	Attorney and Environmental Activist	March 4h 2010	Albuquerque , NM
Filiberto Cortez	Chief Office Manager at the US Bureau of Reclamation, El Paso Field Office	March 10th 2010	El Paso, TX
Gonzalo Bravo	Communications Manager for the Comisión de Cooperación Ecológica Fronteriza /COCEF)	March 22h 2010	Ciudad Juárez, Chihuahua
Gabriel de los Cobos	Principal Engineer at the Service Cantonal de Géologie	January 20th 2010	Genève , Switzerland
Gilberto Esqueda	Project Manager for Degremont, a subsidiary of SUEZ International	February 24h 2010	Mexico City , Mexico

Helen Ingram	Political Scientist	March 17h 2010	Tucson, AZ
John Hawley	Hydrogeologist at the New Mexico State University	March 5h 2010	Albuquerque
Karl Wood	Director of the New Mexico Water Resources Research Institute at the New Mexico State University	March 9h 2010	Las Cruces, NM
Nicolas Levrat	International Lawyer at the Université de Genève	January 20h 2010	Genève , Switzerland
Oscar Ibáñez	Advisors Coordinator for the General Secretary at CONAGUA	February 23h 2010	Mexico City , Mexico
René Franco Barreno	Director of Franco & Asoc. Consulting	March 8th 2010	Ciudad Juárez, Chihuahua
Raya Stephan	Legal Consultant for the UNESCO International Hydrological Programme	December 18h 2009	Paris , France
Sally Spener	Public Affairs Official at the International Boundary and Water Commission (IBWC)	March 22h 2010	El Paso, TX
Scott Reinert	Chief Hydrogeologist, El Paso Water Utilities (EPWU)	March 22h 2010	El Paso, TX
Zhuping Sheng	Hydrogeologist, Texas A&M University	March 22h 2010	El Paso, TX