Spatial Dimensions of Land Administration and User Rights over Groundwater: Case study of Kerala, India vs. Coca Cola

Tarun GHAWANA (India), João P. HESPANHA (Portugal), Jaap ZEVENBERGEN and Peter van OOSTEROM (The Netherlands)

Key words: Groundwater Rights, Domain Modelling, LADM, Spatial Dimension

SUMMARY

Supporting the management of rights related to groundwater based on input from hydrogeology software is contributing to bridging the gap between the technical and administrative aspects of groundwater management. The research reported herein is focused on a specific example (or 'use case' in UML terminology), resulting from a court action by Kerala State in India, against the Coca-Cola company, on the overexploitation of the local groundwater aquifer.

The use case reports on the economic and policy contexts conducing to the establishment of the Coca-Cola bottling plant in Plachimada, and the ensuing court actions, triggered by the local community assembly first, and then by Kerala State authority, on the grounds of the introduction of toxic waste into the groundwater, making the water unfit for human consumption, and the depletion of the aquifer.

Considering the specifics of the use case, the ISO/TC211 Land Administration Domain Model (LADM, DIS 19152) is used as a basis for the development of a specialized profile addressing the need to define laws and regulations with proper spatial and temporal dimensions, to represent the rights to groundwater use by the local communities. Two alternative scenarios are reported: the first is based in the consideration that all the different Property parcels are regulated by Private Law; the second, further develops on the consideration of groundwater as a Public Trust, thus regulating private use through the Public Law domain.

The modelling here provided goes from a subset of the LADM conceptual classes to more specialized classes, and is reported through the use of class and instance level (object) diagrams. These build on the existing spatial unit package and the legal and administrative profile, demonstrating the flexibility which can be introduced by LADM. Specifically concerning the representation of spatial units, a previously proposed 'Mixed 2D/3D' spatial profile is further developed, addressing the needs of the use case. In combination with the 'Level' representation of LADM to organize spatial units, it can contribute to an easier reuse of existing, 2D based, land parcels data, into the proposed 3D and time based model architecture.

Concluding, the modelling and architectural framework here reported contributes to a more informed decision in the choice of groundwater rights to be made by the law, policy and courts, taking into account societal needs and changes induced by new socio-economic contexts. The resulting institutional setting will be best informed with spatial and temporal data, and the legal solution chosen be it public or private law focused, can be recorded in a

system based on the LADM standard; it allows for much flexibility and only a few specific classes need to be added and further specified in order to be implemented.

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1. INTRODUCTION

Developing countries have opened up their natural resources for foreign multinational companies after adopting a more liberal approach towards the concept of free trade and open market systems. India and China are the leading examples of this trend. Trade is no longer limited to buying and selling of goods and services but it encompasses issues like Intellectual Property Rights, exploitation of resources, mobilizing capital etc. (George, 2010).

Some developing countries have land laws pertaining to the era when they were colonized or were acting more as a closed economy (Simpson, 1984). These laws may or may not have enough power to protect the basic rights of a community over the local resources when a commercial venture is started in an area by a multinational private enterprise on a large scale. Many states, including developing states and those in transition, struggle unsuccessfully to apply and enforce groundwater regulatory regimes. A number of North Indian states have debated groundwater laws for some 30 years with little progress as regards enactment (Hodgson, 2004). Although in China water rights are owned by the State, in practice in many (rural) areas groundwater is pumped by land use right holders as if it is part of their land use rights. Surface water and groundwater are still treated independently although there is political attention for the need to integrate them (Zhu, 2009). A private enterprise, gaining the rights to use such common resources, can disregard the shared rights of the local communities.

Owning the natural resources like water (surface and groundwater) by transnational corporations raise questions such as how do ordinary citizens become involved in this process and what are the laws which are needed to protect the resources (Barlow, 2003). With land, forest and water in the open market, life and culture turns corporatized, slowly legitimizing an unquestionable political and social control over people (George, 2010).

2. PROBLEM STATEMENT

In India, US consumer products multinational company Coca-Cola has installed many bottling plants in several parts of the country. In southern India, in the state of Kerala, Coca-Cola bottling plant is accused by the local community and later by relevant authorities to overexploit the groundwater resources beyond the natural recharging capacity. The over-exploitation has resulted in economic, environmental and subsequently health related problems for the locals.

3. OBJECTIVE

The main objective of this paper is to address the need to define laws and regulations with proper spatial and temporal dimensions to defend the rights of local communities over the natural resource use in the area. The paper highlights the spatial information science approach as an efficient mechanism to provide required scientific inputs for the policy making related to natural resources like groundwater. It discusses the Kerala state groundwater case in India against the Coca-Cola bottling plant as a use case to be later generalized as an extended approach under the Land Administration Domain Model (LADM).

The LADM is a standardization effort lead by ISO/TC211 for Geographic Information respecting a conceptual schema focused on the rights, restrictions and responsibilities affecting land (in the widest sense, including resources like water), and the spatio-temporal components thereof. As stated in the introduction to the Draft International Standard document, it is not intended to be a data product specification (ISO/TC211, 2011).

This paper is the natural sequel of a previous paper presented to FIG Congress 2010, dedicated to generic problems with groundwater management in Land Administration and the contributions LADM can give to this problem domain (Ghawana et al, 2010). It was stated then that:

"Further research will be needed to fully operationalize and implement such data models, which ultimately could produce outputs at case study level which can help to formulate policies regarding natural resources, more on the basis of technical inputs".

The current paper takes this recommendation further, by detailing previous modelling results in face of a selected (and exemplary) use case.

4. RIGHTS TO GROUNDWATER – EXISTING LAWS

In many jurisdictions, water rights have for a long time been considered as a subsidiary component of land tenure rights, a right to use water often being dependant on the existence of a land tenure right (Hodgson, 2004, 2006). This means that the right over a piece of land gives the land owner largely a right to the water above and below the surface with some scope considering the independent nature of subsurface water flows. It is important to emphasize that European conceptions of water and water law have strongly influenced the development of formal water laws around the world, through the two principal European legal traditions: the civil law tradition and the common law tradition.

4.1 The Civil Law Tradition

Within the civil law tradition, by its turn in accordance with the basic principles of Roman law, groundwater is seen as the property of the owner of the land above it. This basic approach is reflected in article 552 of the French Civil Code. Although the code contains dispositions concerning the flow of surface waters, it does not elaborate on the flow of groundwater. For example, the related Portuguese Civil Code only restricts the extraction of ground water if it affects the supply of a public fountain (article 1396). In parallel to the Civil

Code, many countries have introduced regulations regarding groundwater through public law instruments, usually restricting the owner's water rights (e.g. the Netherlands).

4.2 The Common Law Tradition

Although the conceptual approach taken by the common law tradition is slightly different, the effect is largely the same. The effect is that a land owner is entitled to sink a borehole or well on his land to intercept water percolating underneath his property, though the effect might be that it interferes with the supply of underground water to nearby springs. Yet at the same time, the owner of land, through which ground water flows, has no right or interest in it which enables him to maintain an action against another landowner whose actions interfere with the supply of water.

In current practice, however, as a result of the development and use of modern well drilling techniques and pumps, the approaches of the main legal traditions no longer offer a viable means of effectively regulating the use of groundwater, even though they continue to apply in a number of jurisdictions. A clear example of the inadequacies of traditional land-based approaches is provided by the experiences of their inability to prevent the depletion of aquifers, for example in Texas where groundwater provides about 60 percent of the water that is used each year particularly for irrigated agriculture and urban water supply (Hodgson, 2006). Due to the risk of salinization from the nearby ocean, around Los Angeles, California, this approach could not be sustained. There was already a legal difference between overlying owners (for water they could use productively on the land) and junior appropriators (who could only take surplus water of a basin when use was below the average replenishment rate). Partly through negotiations and partly through court actions, several basins arranged themselves into water districts around the 1950s. The districts restricted pumping rights to those already pumping before, mostly ending the difference between the two types, and reduced them to find a balance. But also for instance technical measures to increase replenishment and prevent salinization were taken. (Ostrom 1990).

5. USE CASE BACKGROUND

Coca-Cola Company opened in the year 2000 a bottling plant in Plachimada in the Palakkad district of Kerala state of India, on a subsidized rate as part of an industrialization policy. This part of Kerala is called the 'rice bowl' of the state because of producing almost 35% of state's rice production despite being in a 'rain shadow' region. The villagers are predominantly landless agricultural labourers with almost 80 percent of the population depending on agriculture (High Power Committee, Kerala State, 2009).

In 2002, indigenous people started protesting against the Coca-Cola bottling plant. Accusations were over-extraction of the groundwater using more bore wells than permitted by state. Coca-Cola was also accused of discharging the toxic waste back into the ground water. The groundwater ceiling level reduced from 45 meter below ground level to 100 meter. Local people also complained about smelling water and health related problems. In 2003, the local aquifer's water was declared unfit for consumption by the district medical officer. An analysis showed a high level of dissolved salts in the water.

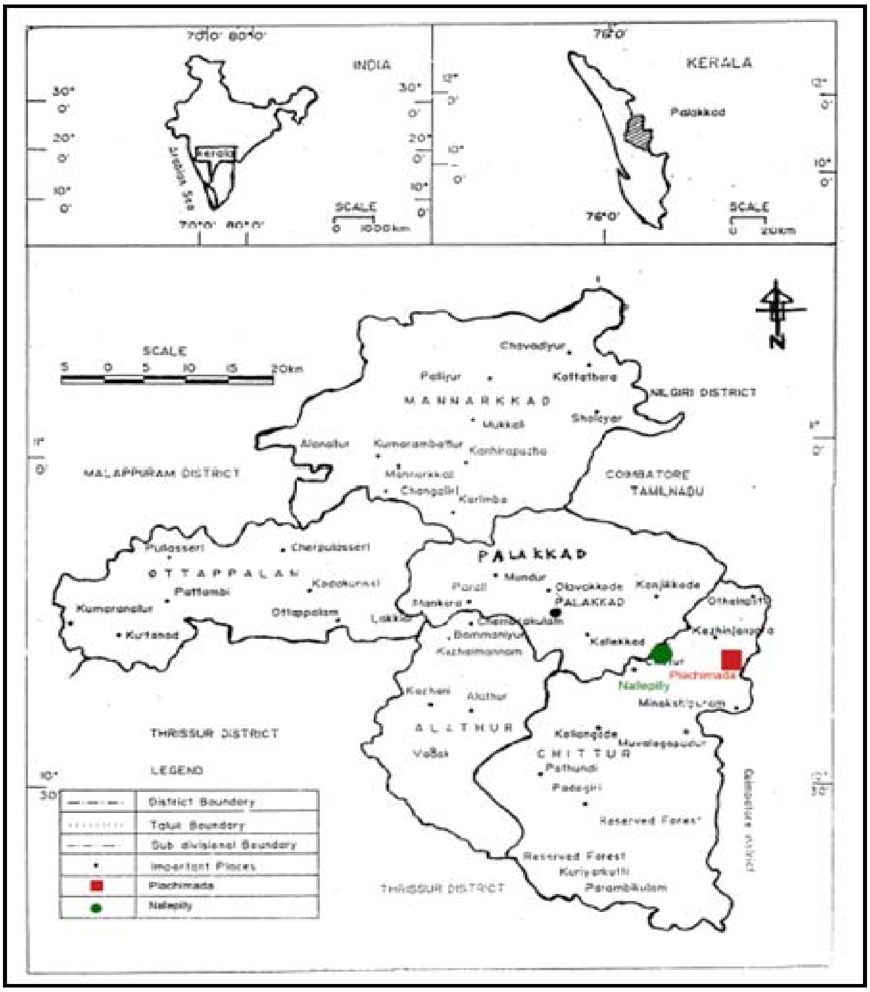

Figure 1 - Location of Coca-Cola Plant at Plachimada.

5.1 Legal Battles: Kerala State vs. Coca-Cola Co. and other Court Actions

In April 2003, the village council called Panchayat (the democratically elected local level unit of administration), Perumatty Panchayat cancelled the Coca-Cola license to operate the bottling plant in the area. This led to legal battles over the years which are summarized here:

- March 2000 – Factory established
- April 2002 – Agitation by the villagers commences
- March 2003 – Village Council refuses to renew license
- May 2003 – State government confirms the Village Council decision
- Dec 2003 – Single judge bench of the Kerala High court upholds the Village Council's decision
- 21 Feb 2004 – The Government ordered the company to stop drawing ground water from the plant
- 12 March 2004 – Coca-Cola company suspended production saying it was "left with no option but to close the factory down in the long run"

- 29 March 2004 – Village Council refused to renew licenses again saying company had failed to meet conditions to: stop using ground water; demonstrate that its products were safe, and prove the non-toxicity of its solid waste
- 3 April 2004 – Irate villagers blocked tanker lorry taking water to the plant and police arrested 44 villagers
- April 2005 – A High Court Division Bench allows appeal by Coca-Cola and permits the company to draw 500,000 liters of water per day. Orders the Village Council to renew license
- May 2005 – Village Council files special leave petition in the Supreme Court
- 1 June 2005 – Company approaches the High Court again as the Village Council did not renew the license. The court orders Village Council to renew the license within 7 days, or it would be deemed that the license stands renewed for two years from 10 June 2004
- 6 June 2005 – Village Council informs the company that license will be renewed for three months; asks them to remit the fee and collect license
- 17 August 2005 – A group of about 100 activists from Yuvajana Vedi youth organization march to factory gates. Heavy police force severely injured 4 protestors who were hospitalized and arrested 43 activists
- 19 August 2005 – The Kerala State Pollution Control Board ordered the stoppage of production at the Plachimada factory for failure to comply with pollution control norms
- 15 September 2005 – Kerala State Government lends its support for the people against the company
- November 2005 – High Court rejects the company’s petition that since Village Council did not keep up the stipulated time frame, it should be deemed that the license stands renewed for two years. The company ought to have accepted the opportunity to function for three months. But the court again orders the Village Council to renew the license
- November 2005 – Village Council files against the latest High Court order in the Supreme Court
- 4 Jan 2006 – Village Council reissued a license to the company for three months but laid out thirteen conditions, the first of which is that the company shall not use groundwater from Perumatty Panchayat for industrial purposes, or for producing soft drinks, aerated carbonate beverages or fruit juice
- June 2006 – Meeting with community leaders ends in major commitment from Kerala state officials for pro-active action against Coca-Cola
- 10 August and 11 August 2006, the Government of Kerala and the State Food (Health) Authority, respectively, banned the manufacture and sale of Coca-Cola in the State on the grounds that it was unsafe
- September 2006 – High Court of Kerala set aside the orders of the Government of Kerala and the State Food (Health) Authority

The bottling plant has not worked since 2004. During this legal battle a total of five Special Leave Petitions (SLP) were filled with the Indian Supreme Court appealing the Kerala High Court decisions in favor of the company: One was by the Kerala Pollution Control Board, One by the Kerala state government and three by the Village Council. Supreme Court has not made so far any significant ruling (Right to Water Info).

5.1.1 Ownership of water: December 2003 Kerala High Court decision

The first judgment in 2003 rested on Public Trust Doctrine and Article 21 of the Indian Constitution. Public Trust Doctrine is part of common law, inherited from the English legal system on which the Indian one is based; it is the principle that certain resources are to be kept for public use, and that it is state responsibility to uphold this. The reasoning of the judgment in this case was that groundwater is a public resource and therefore it is the responsibility of the state to protect it.

With regard to the Plachimada bottling plant the most significant part of this verdict is arguably that:

"Even assuming experts opine that the present level of consumption by the second respondent is harmless, the same should not be permitted"

The reasons given for this is that the company which is a commercial private enterprise has no right to claim such a large share of a public good, and if they were permitted to do so, others would also be able to claim this right.

5.1.2 Ownership of water: April 2005 Kerala High Court decision

The April 2005 court case reversing this judgment does so on the basis of a report on the extraction of groundwater: made by an expert committee nominated by the Kerala High Court. This judgment is considered in different ways, depending on the perspective of the actor (Coca-Cola case in Kerala, India).

5.2 Damage Assessment: Results from the High Power Committee of Kerala State

For Plachimada case, government of Kerala, on a recommendation by the State Ground Water Authority, constituted a High Power Committee in May 2009 with the mandate of 'assessing the scale and nature of the damages'. The committee had members from different disciplines so as to facilitate a proper appreciation of this multi-sectorial crisis.

Two major reasons are cited for constituting this committee. Firstly, although the extent of damages and their inter-sectorial linkages were understood and the culpability of the company was established, no attempt was made to quantify these damages. Secondly, there was no well defined proposal about a legally tenable institutional mechanism to claim compensation from the company.

Such an exercise has no precedent in the state. The committee had therefore to evolve its own strategies and methodology to arrive at a meaningful assessment, rational conclusions and practical recommendations. The committee conducted a public hearing at Perumatty Panchayat office which was attended by hundreds of affected people, voluntary workers, concerned citizens and Panchayat representatives. On publishing the notice for the public hearing, the Coca-Cola Company had issued a letter questioning the validity and justification of the constitution of a high power committee. However, it did not pose any difficulty since as per Article 323 B of the Constitution of India, state legislature has powers to create tribunals for any dispute.

In order to take stock of the scientific and legal ramifications of the various hardships highlighted during public hearing, two panel discussions with experts were organized. One focused on various issues related to water resources, agriculture and health. The second discussion was solely on the legal and environmental aspects.

The committee came to the conclusion that the company is responsible for the damages to the community resources and it is obligatory that they pay the compensation to the affected people for the agricultural losses, health problems, loss of wages, educational opportunities and the pollution caused to the water resources. The value of water extracted and depleted has not been calculated though it needs to be compensated (High Power Committee, Kerala State).

5.3 Assessment of Water Level Depletion using GIS

The following paragraphs show some examples of contributions that spatial information sciences can provide in support for a technical discussion of this Use Case.
In addition to rainfall patterns study, Committee report mentioned that the water level data collected by groundwater department has been analyzed using GIS techniques. This was done in order to get a clear picture on water level scenario during post monsoon period in the area. The water level zonation map developed using December 2002 data indicates that the water level decline is highest in the area near to the Coca-Cola factory (Figure 1.). Zonation map also indicates that during December 2002, the drop in water level in the phreatic aquifer system was 10.6 – 12 meters in the area. In the north and central part of the block, the depletion in the groundwater resources was comparatively very less during post monsoon period. This is a clear indication of the exploitation of groundwater by Coca-Cola Company.
Water level data for May 2003 has been analyzed using GIS tools to get a scenario on the water level during pre-monsoon period. Generated water level zonation map clearly indicates that the maximum depth to water level in the phreatic aquifer was near to the Coca – Cola factory area and the value ranges from 11.4-13 meter below ground level (Figure 2.). This also substantiates the over exploitation of ground water by the factory. It may also be noted that area other than the neighboring area of Coca-Cola Company are less affected.

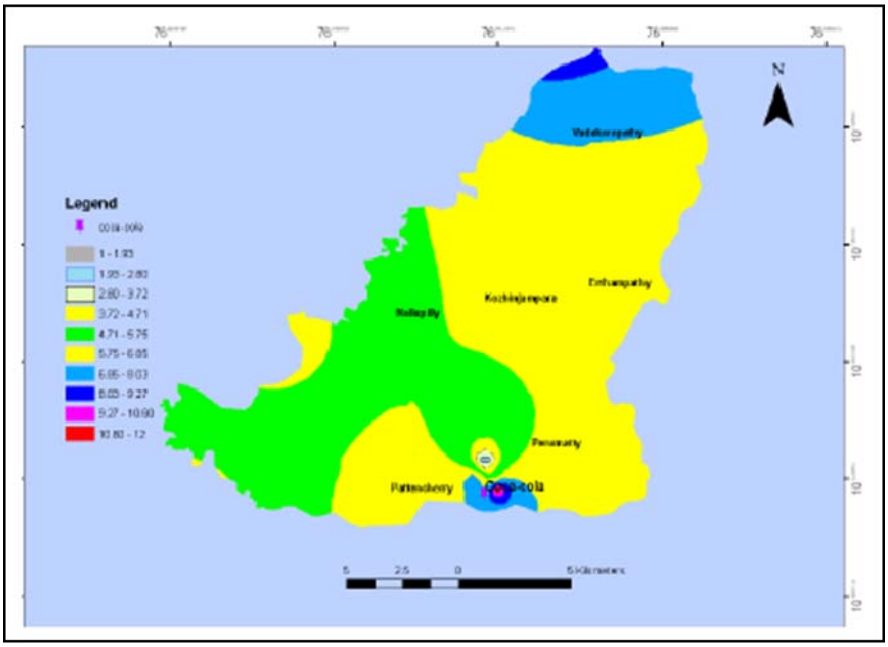

Figure 2 - Water Level Zonation map during December 2002

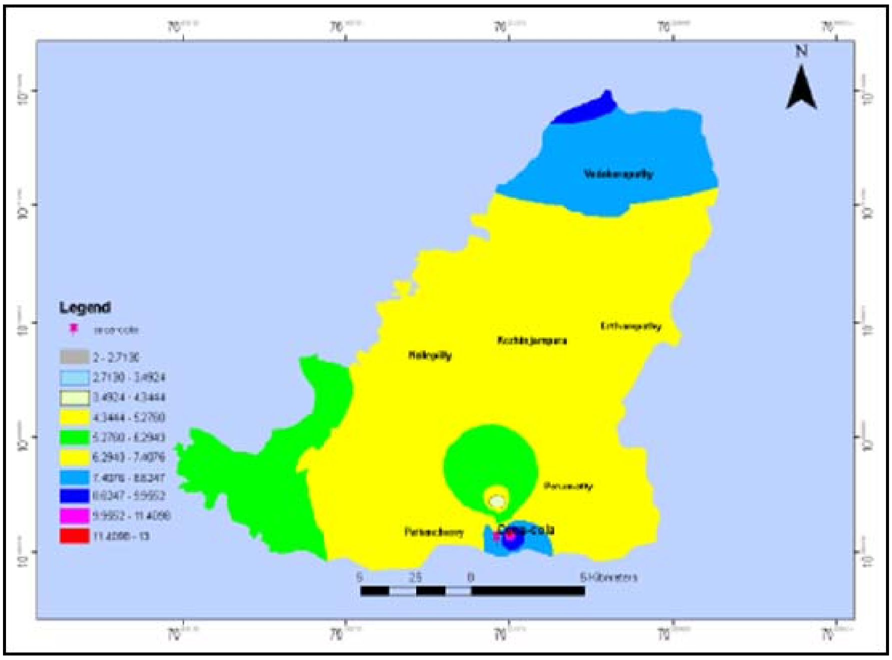

Figure 3 - Water Level Zonation map during May 2003

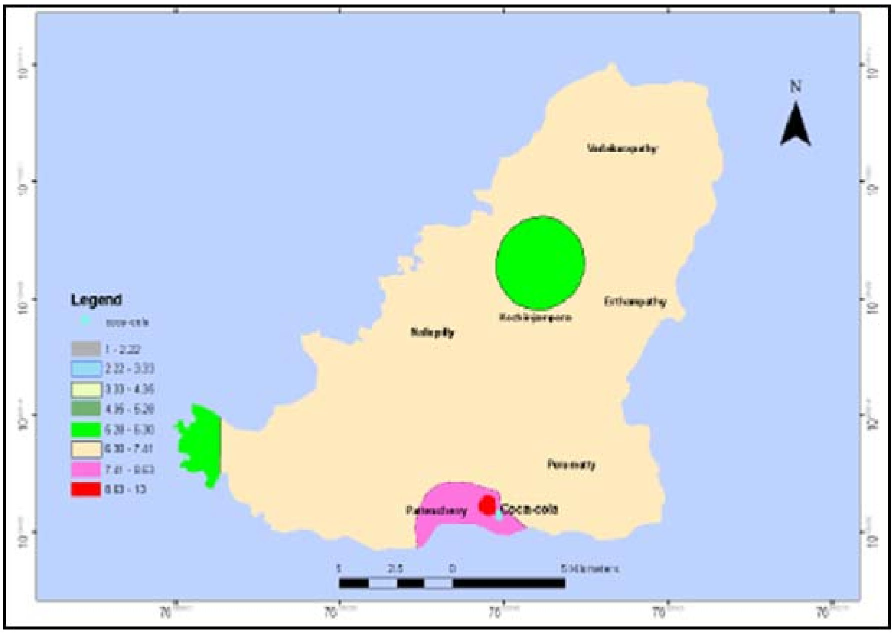

Figure 4 - Water Level Zonation map during May 2004

On analyzing the water level data for May 2004 (Figure 3), it is clear that water level is showing a rising trend when compared to the previous years. During May 2004, the average depth to water level ranges from 8.63 -13 m below ground level. This can be interpreted as an indication of stoppage of groundwater extraction by the Coca-Cola, resulting in recuperation trend. This is further confirmed by the results of the data for March 2006 which show the water level in the phreatic aquifer system around the Coca-Cola factory area as ranging from

5-6 and 6-7 meters below ground level (Figure 4.). This indicates that the water level in the area has recouped by natural recharge mechanism. The water level zonation maps for different periods depict a clear picture of the trend of water level during the period when the factory was in operation.

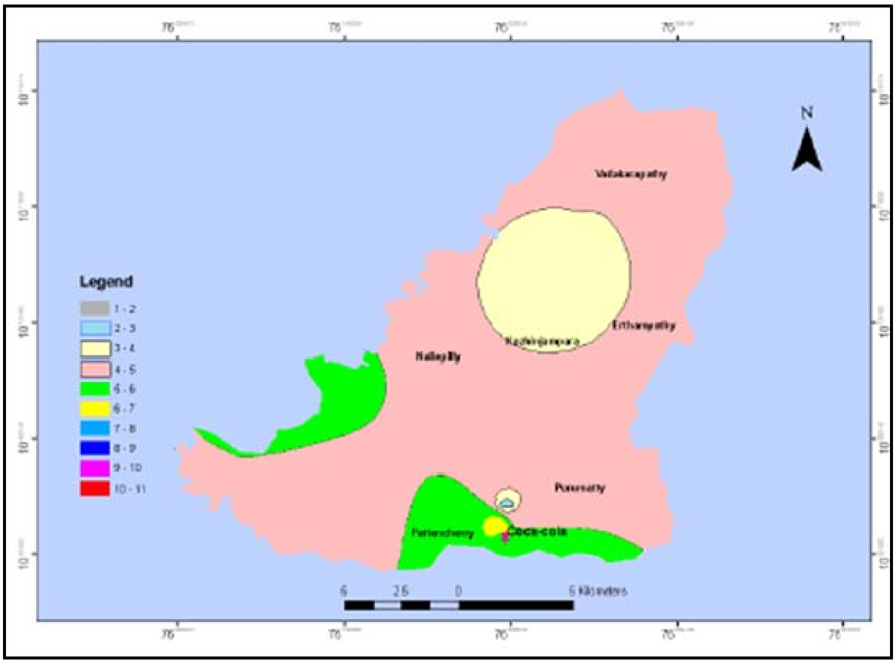

Figure 5 - Water Level Zonation map during March 2006.

6. GROUNDWATER DATA MODEL

In our earlier paper (Ghawana et al., 2010) the groundwater data model of the popular commercial GIS software company ESRI was presented. The model considers the spatial (2D & 3D) and temporal dimensions also of the groundwater datasets. It includes the surface and subsurface features including watershed boundaries, surface water bodies, wells and boreholes, geological features. The simulation generates multipatch texture classes for 3D Cells.
The data model design outlines three components for the data model: Hydrogeology, Simulation, and Temporal information. The Hydrogeology dataset includes representations of two-dimensional features such as wells and aquifer outlines, and three-dimensional classes to describe hydrostratigraphy, solid volumes, and cross sections. Temporal information is represented with the ArcHydro tabular structures such as TimeSeries and TSType (TimeSeries Type) tables. The RasterSeries raster catalog represents gridded temporal information (ESRI, 2009).

6.1 Groundwater Legal Model – Scenarios

The previous paper (Ghawana, 2010) proposed a number of scenarios for diverse relationships between people and specific groundwater rights. Those scenarios considered a more elaborate classification of Rights and Restrictions, following the so called “Legal Profile” presented in LADM (as informative annex, ISO/TC211, 2011). The aim was to model situations which can be found globally. From the set of presented scenarios, one is selected for further development, given that it is an alternative to consider in the specific case of the Coca-Cola bottling plant dispute. This is the “Private shared use of a collective resource”, also termed a “joint facility parcel”, and constitutes the Private Law based alternative. A new scenario, still based on the LADM Legal Profile, is then introduced as the Public Law based alternative. This last one considers the common law doctrine of Public Trust, as invoked by Kerala High Court. In both scenarios, the LADM is the foundation for the presented modelling.

6.1.1 Private law based alternative: Private shared use of a collective resource

This could also be called a “joint facility parcel”. As in the classic land parcel counterpart, the ownership is shared by a number of related land parcels (and only indirectly to personal owners). Such a joint facility needs to be distinguished from a servitude or easement, since there is no main owner of the parcel letting others do certain things on it. This way, corresponding individual shares should be defined, according the areas of the related land parcels (the “served parcels” in Fig. 6), which can be spatially adjoining or superimposing the joint facility parcel. In terms of real rights, each of the related land parcels ownership has an appurtenant derived right of the Common Right type. This scenario can accommodate water users associations, regulated by private law and which will represent all the individual (personal) owners of the related land parcels, in the role of a “group person” with the aim to manage the joint facility parcel resources. This description, which has been centred on rights so far, is completed with two other components:

1. A class diagram representation (Fig. 7) which builds on the classes and model elements contained in LADM and depicts the different packages which were used to build the instance level diagram (Fig. 6) for the joint facility parcel;
2. A possible spatial profile, the “mixed 2D/3D profile” (Fig. 8), developing existing LADM profiles, while addressing specifics of the joint facility parcel spatial-temporal representation.

6.1.2 Instance level representation – Private shared use of a collective resource

An Aquifer (groundwater volume) is modelled as a ‘Joint Facility’, which is underneath the served (surface) land parcels. Here each party will own a share which could be proportional to the volume of the aquifer delineated by the surface parcel boundaries and / or the temporally divided right delineated again by the surface parcel.

Figure 6 shows the instance level diagram for groundwater joint facility in context of Plachimada. Major identified stakeholders are Coca-Cola company, a private enterprise; individual farmers owning a rural parcel; and a Community/ Panchayat as a group / group representative. Each of the stakeholders owns surface land parcels with specified boundaries and different land uses. The common share is defined in terms of right to water held by the related surface land parcels (in the role of parties (persons).This type of Right is referred to as a “Common Right_A” in Fig. 6, where “A” stands for Appurtenant. This common source of water is defined as the shared aquifer (as a joint facility) under the served surface land parcel units with exclusive rights belonging to each party. These rights are attached to the respective Basic Administrative Units (type: LA_BAUnit) of the served Parcels, but are not shown in

Fig. 6. What is shown is the LA_BAUnit object named as "Aquifer Register", representing the administrative record of the Joint Facility Parcel[1]. The bottom part of Fig. 6 shows the spatial representation instances (of LA_BoundaryFace and LA_BoundaryFaceString), which are associated to the Aquifer serving parcel. This component is detailed in Fig. 8, depicting the spatial component as could be implemented using a Mixed 2D / 3D spatial profile (Lemmen et al., 2010, p.15-20).

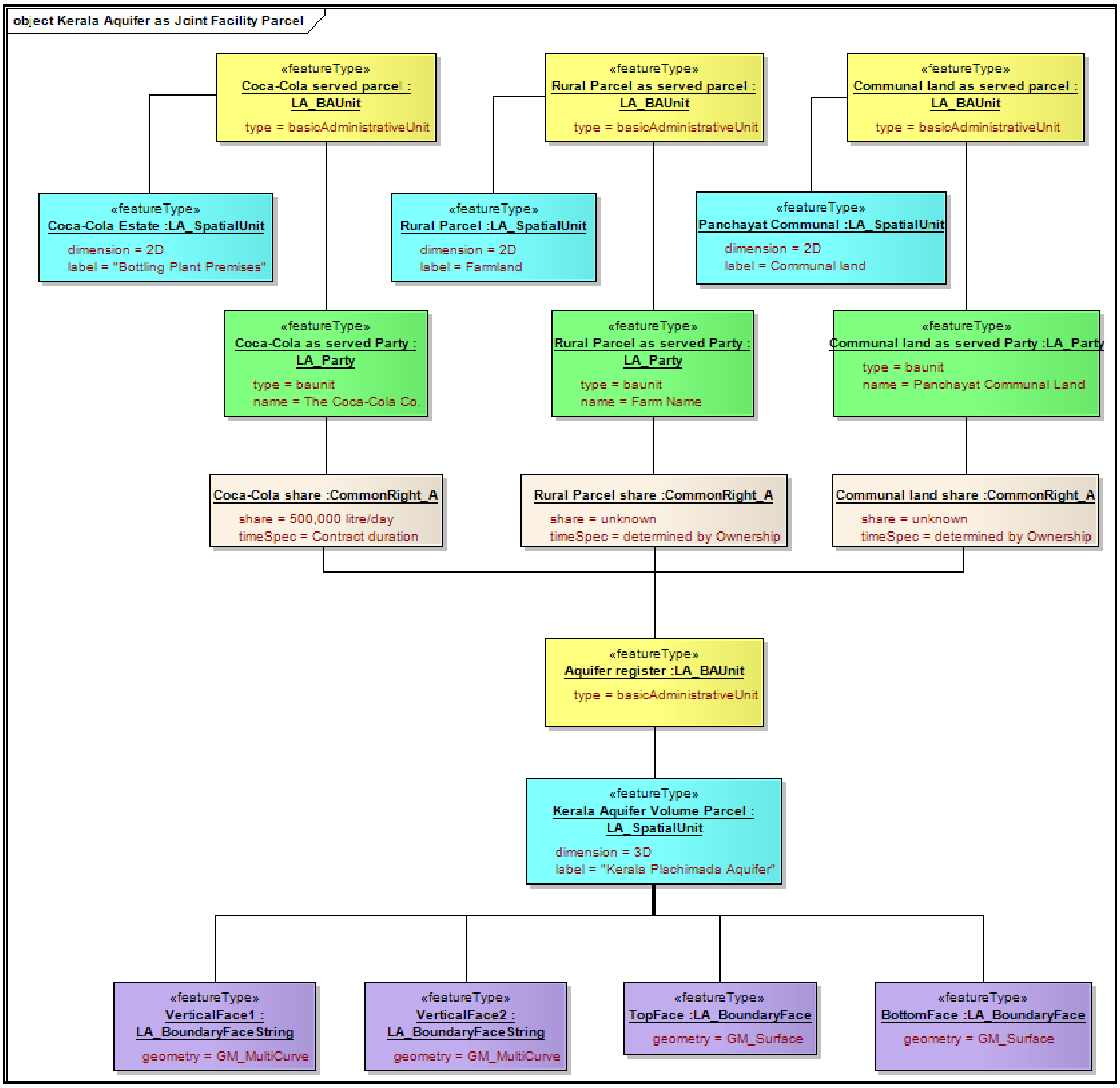

Figure 6 - Instance Level for the Kerala-Plachimada Aquifer as a Joint Facility Parcel

[1] In some countries, like Portugal, there is a dedicated register (separated from the Land Registry) which records private and public boreholes and wells in use for water supply (INSAAR, 2011).

6.1.3 Spatial Profile for the Joint Facility Parcel

Supported on the separation of concerns referred in (Ghawana, 2010), the spatial component to be considered in a system of Land Administration does not have to maintain the resolution, data formats, or even the topology of the corresponding feature as depicted in a technical system (eg., an ArcHydro model of the serving groundwater parcel). This is because the Land Administration system is concerned with the registration of the legal space of this parcel.

The LADM includes a number of spatial profiles in informative annex E (ISO/TC211, 2011), where to base a specific modelling in a particular country, or in the case, a particular type of spatial feature. These last types can be distinguished on the basis of the spatial component class "LA_Level", so an additional level would be in order to include all the surveyed groundwater parcels in a jurisdiction.

A joint facility parcel, or other type of groundwater parcel, given that refers to a particular arrangement of rights and does not have spatial implications, can be logically represented by a volumetric or 3D parcel, as is shown in Fig. 6. However, currently LADM (ISO/TC211, 2011) just defines a Topologic 3D spatial profile, as far as 3D representations are concerned. But other profiles could be defined using the same spatial representation classes in LADM, namely those presented in the paper (Lemmen et al., 2010) on the modelling of spatial units.

In this last case, a mixed 2D / 3D representation or spatial profile is achieved by using both LA_BoundaryFace (3D polygon) and LA_BoundaryFaceString (2D polyline, implying string of vertical faces) classes. This is a possible solution for the joint facility parcel, which combines surface and volumetric land parcels.

The situation regarding (some of) the objects in the preceding instance level is used for the following two-part diagram, depicting the classes in the spatial profile and other LADM packages involved in modelling the joint facility parcel (Fig. 7), and the corresponding instances (Fig.8) concerning just the spatial component.

The class diagram in Fig. 7 includes all the classes required for the previous Instance Level, with some simplifications and added constraints in relation to LADM. It should be noted that both LA_BAUnit and LA_SpatialUnit classes have a double role in the joint facility parcel case. The LA_BAUnit can act as a Party for the served parcels, but should equally represent the Aquifer register. For the LA_SpatialUnit, the role can be the representation of the surface land parcels (with association to 2-dimensional features), or the representation of the groundwater aquifer, which is a 3-dimensional feature but it is assembled from a mix of 2D and 3D features, as is shown in greater detail in Fig. 8.

The diagram also attaches a number of OCL expressions to some of the classes, to formalize constraints to be validated during implementation.

The instance level diagram for the Mixed 2D / 3D spatial profile (Fig. 8), applied to the joint facility parcel, is complemented with a geometric diagram as an example of the corresponding field situation (Fig. 9). For this spatial profile, no corresponding class diagram is shown.

This instance level shows the objects belonging to the spatial unit package and spatial representation sub-package in LADM, and the type of relationships existing between them.

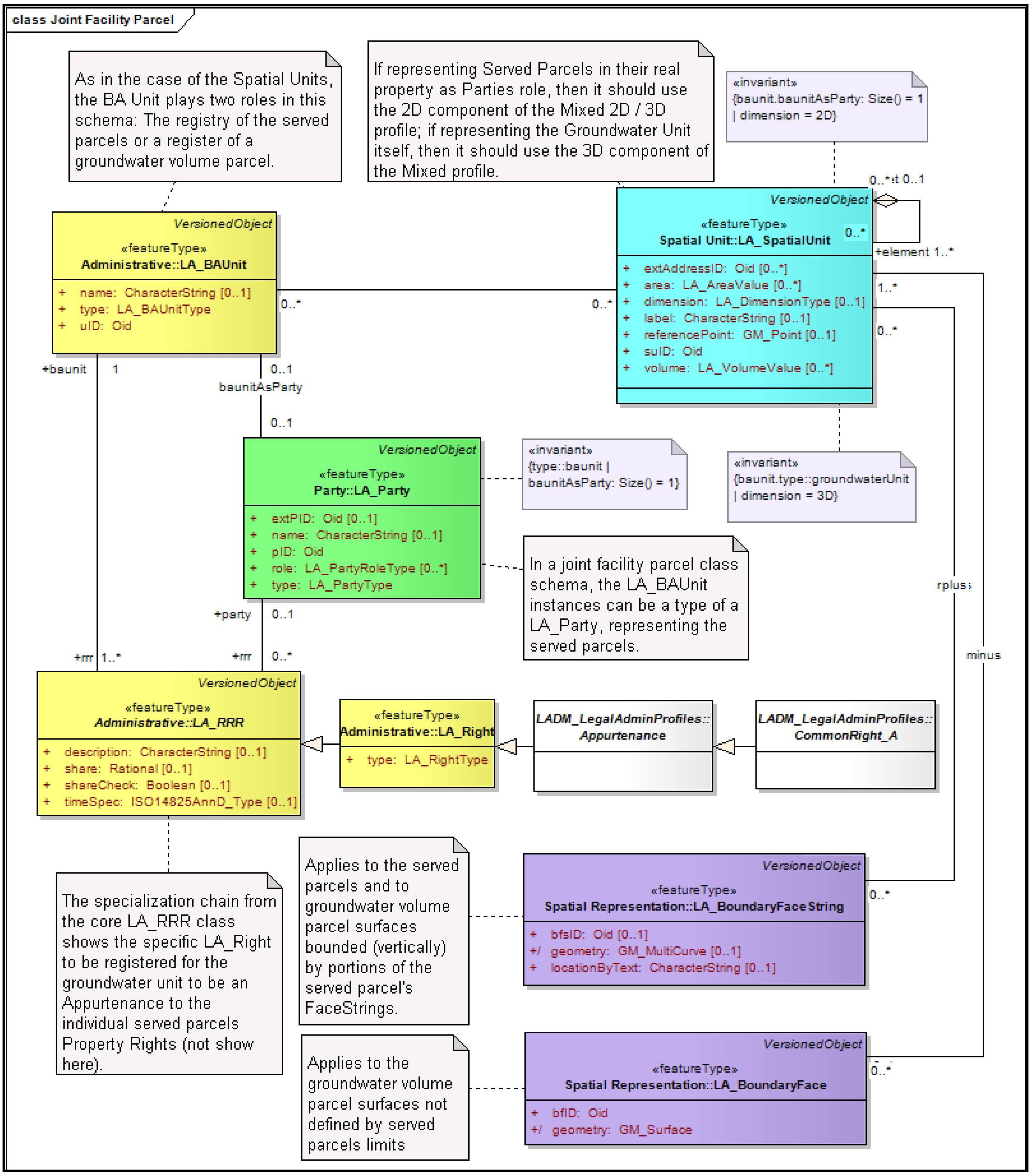

Figure 7 - Class Diagram for the Joint Facility Parcel

There are just two Spatial Units involved, a (surface) rural parcel formed by three Boundary FaceStrings (the "VerticalFaces" in the diagrams), and (a part of) the Kerala-Plachimada Aquifer. This last one is a volumetric or 3D parcel assembled from a mix of 2D FaceStrings and 3D Faces, through the "asPolyhedron" operation. This is shown by the dependency arrows and the «derive» stereotype, in the instance level diagram. The vertical faces, which

are bounded, resulting from this operation, together with the initial 3D Faces, allow then to compute a volume or to visualize the resulting polyhedron.
It must be noted that the vertical faces (1 to 3) represented by the Boundary FaceStrings are unbounded by definition, both upwards and downwards, and they are not shaded in the Fig. 9 diagram. The area of the rural parcel is computed by the closed figure formed by these three Boundary FaceString objects. The horizontal datum used for the jurisdiction (in this case, Kerala State), defines the plane of reference where the Boundary FaceStrings are represented. It is not mandatory then, that the Boundary FaceStrings (as GM_MultiCurve attached to the plane of reference) be situated above the Top and Bottom Aquifer Faces. Besides, in this example, there are no objects defining the actual ground surface, which can rise some problems if a validation of the Aquifer Polyhedron is required.

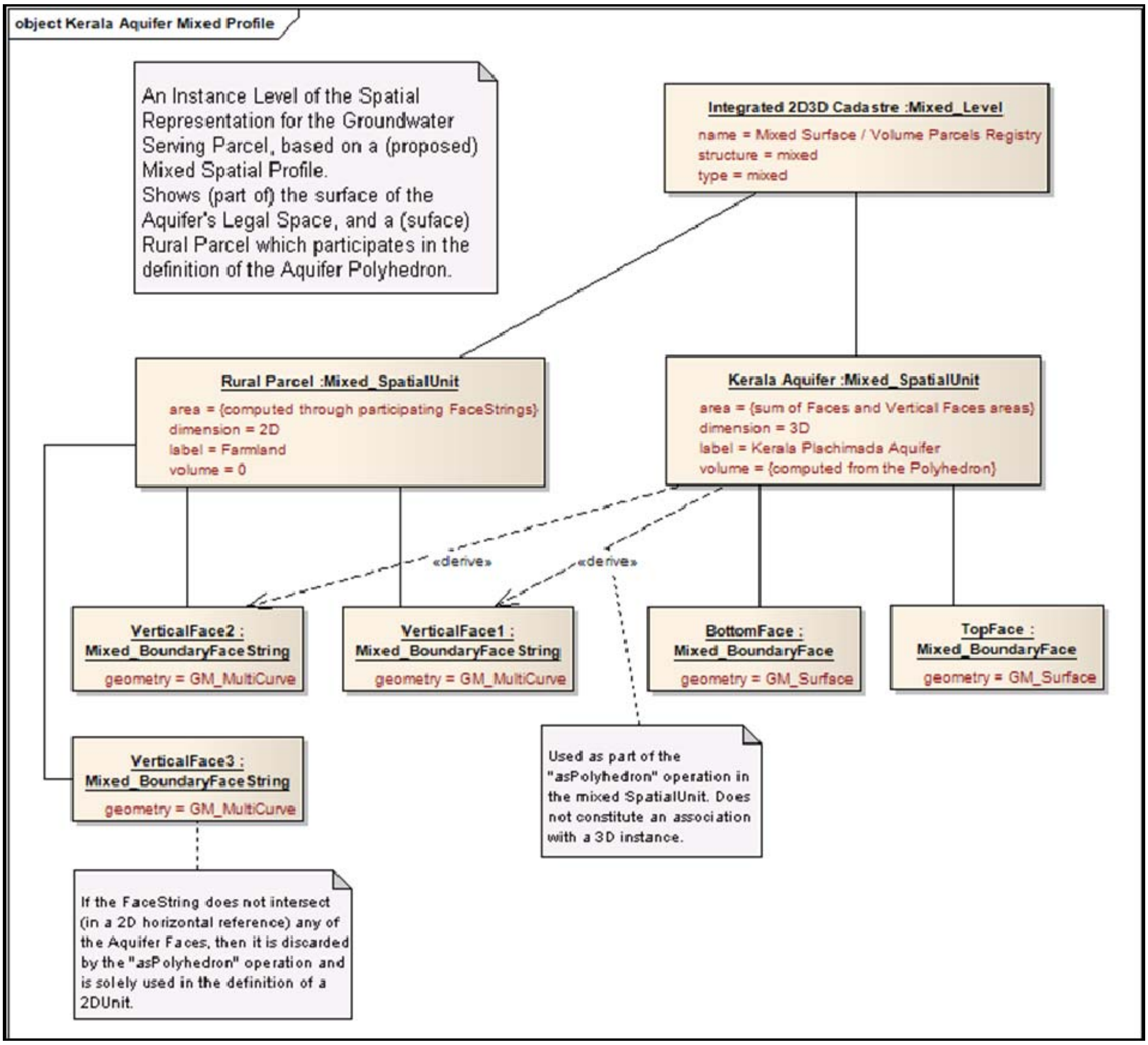

Figure 8 - Instance Level for the Spatial Component

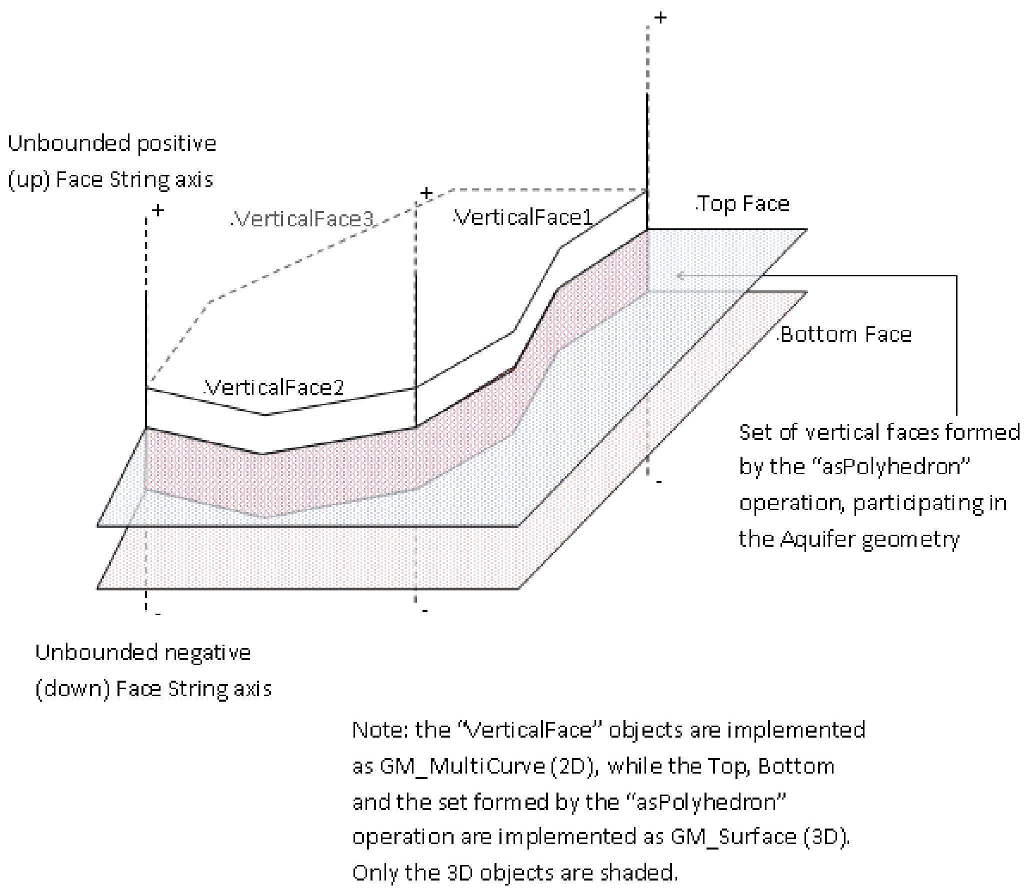

Figure 9 - Instance Level Geometry (example)

6.1.4 Public Law based alternative: Private (regulated) use of a Public Trust resource

This alternative considers that the complete groundwater parcel is a Public resource to be managed by the State authorities. In this second approach, the classical view that the owner of a land parcel owns in fact a semi-boundless volume going from the Earth's centre to the (unbounded) space above, suffers an important restriction, imposed by a Public Regulation. In this view, each owner gets an encumbrance of a new type, because it does not restrict the enjoyment of the usable surface, not even in the same way as an administrative servitude for a sub-surface infrastructure (eg., a gas pipe).

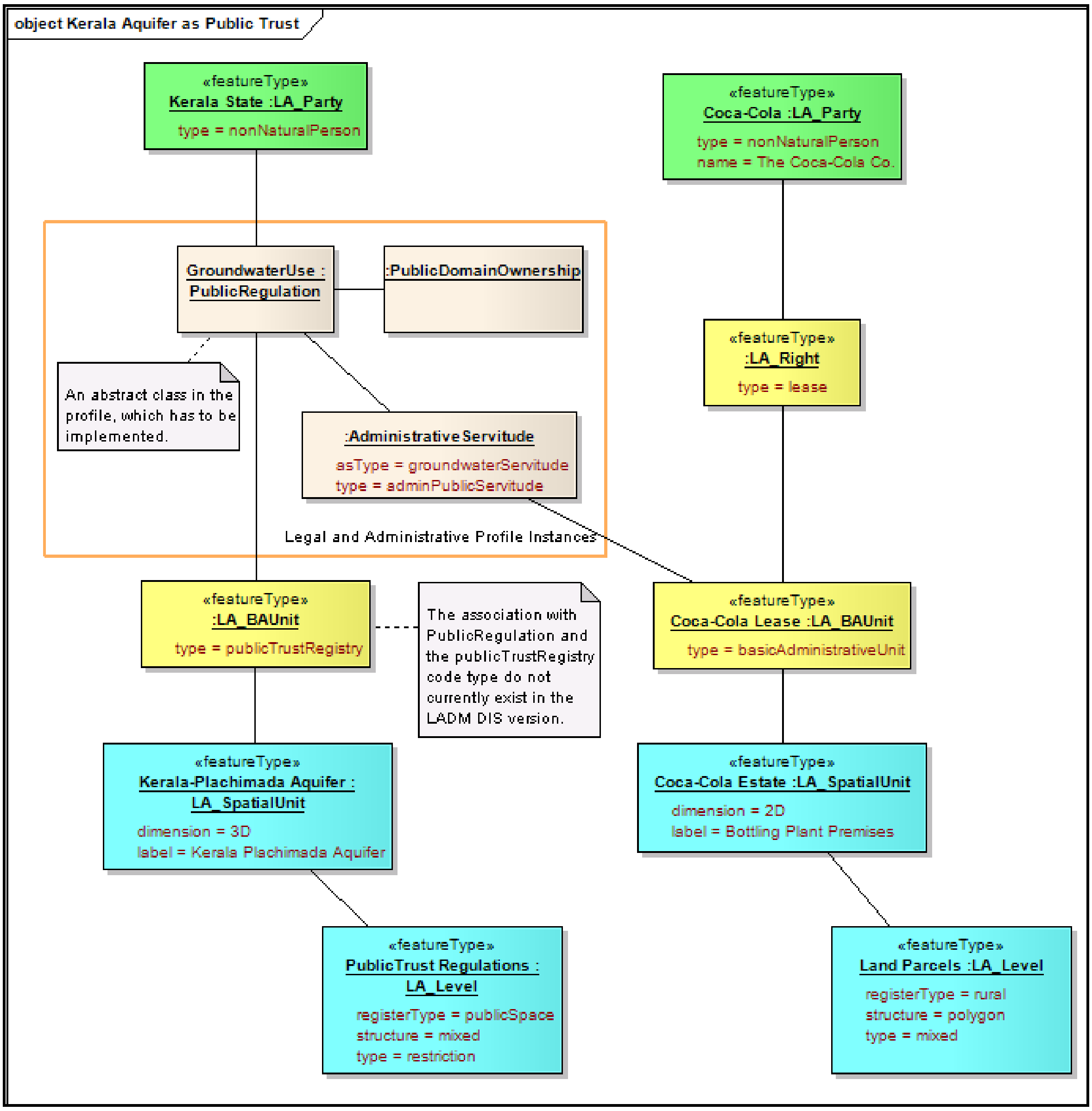

Figure 10 - Instance Level of Kerala-Plachimada Aquifer as a Public Groundwater Resource

The Instance Level diagram in Fig. 10 shows the Kerala-Plachimada Aquifer as 3D Spatial Unit which is registered in a particular type of registry, dedicated to Public Trust domains. This is a specific code type, not existing in LADM as such but that could be extended as proposed. This way, these registers should include Public Regulations for groundwater or other Rights from Public Law, affecting or defining Public Trust domain ownership.

These Public Rights will affect Private Property, in this case represented by the Coca-Cola Estate through a lease right, through Administrative Servitudes. This is a specialization from a LA_Restriction class. Both the Right (lease) and the Restriction (Administrative Servitude) are registered in a conventional land registry (with type “basicAdministrativeUnit” for the LA_BAUnit object). In this simpler alternative, there is just a textual description of the limitations imposed by the administrative servitude. In the implementation, there are separate

registers and separate LA_Level objects, each using a different spatial representation structure (mixed for the Aquifer; polygon for the Land Parcel).
This solution can easily adapt to an organization where there are different government bodies, possibly within different ministries, responsible for a register of private property for one side, and Public Trust Domains for the other. Even for this case, it would be possible to make cross queries through the different registries, if they share some common references. In the diagram, this role could be implemented by the Administrative Servitude.

7. CONCLUSIONS

Changing economic scenarios in the developing countries require the new perspectives to define appropriately the ownership of resources such as land and water. Development of spatial science based approaches in recent times can contribute significantly to the better decision making in context of Land Administration.
The integrated modelling approach using Land Administration Domain Model key elements can contribute to the choice on water rights to be made by the law, policy and courts, taking into account societal needs and changes. The resulting decisions would be best informed be it public or private law focused. The corresponding data model can be recorded in a system based on the LADM standard; it allows for much flexibility and only a few specific classes need to be added (and further detailed, previous to implementation in a given country). Instead of recording the absolute value associated with the right to use joint facilities by a specific party, such as '500,000 liters of water per day', it would also be possible to specify relative shares among involved parties (depending of the recharge levels, which must the be monitored). Groundwater process modeling is outside the direct scope of the LADM, but such a model could be usefully coupled with the LADM data for good estimations of recharges and therefore of groundwater quantity rights for the next time interval.
In the current approach the temporal and spatial characteristics are separate attributes or associations, in future work we'll investigate if a true 4D approach (integrated spatio-temporal representation) would be better; see (van Oosterom et al., 2006).

REFERENCES

Barlow, Maude (2003). Blue Gold: The global water crisis and the commodification of the world's water supply. Special Report issued by the International Forum on Globalization (IFG). http://www.thirdworldtraveler.com/Water/Introduction_BG.html

INSAAR (2011, February) National Inventory of Water Supply and Wastewater Systems http://insaar.inag.pt/

ISO/TC211 (2011), ISO 19152. Draft International Standard (DIS), Geographic information — Land administration domain model (LADM), Geneva, Switzerland, 20 January 2011.

ESRI (2009), Data Models. http://www.dgi.com/earthvision/evarticles/evarticles_main.html

George, Goldy M. (2010, January). Trade, Corporate Market and Indigenous People http://www.countercurrents.org/george190110.htm

Ghawana, T.; Hespanha, J.P.; Zevenbergen, J.; van Oosterom, P. (2010) Groundwater Management in Land Administration: A Spatio-temporal Perspective. Paper presented to FIG Congress 2010, held in Sydney, Australia, 11-16 April 2010

Hodgson, Stephen (2004). Land and Water - The Rights Interface, FAO Legal Papers; Online#36.

Hodgson, Stephen (2006). Modern Water Rights, Theory and Practice, FAO Legislative Study 92.

Lemmen C.; van Oosterom, P.; Thompson, R.; Hespanha, J.; Uitermark, H. (2010) The Modelling of Spatial Units (Parcels) in the Land Administration Domain Model (LADM). Paper presented to FIG Congress 2010, held in Sydney, Australia, 11-16 April 2010

van Oosterom, P., Ploeger, H., Stoter, J., Thompson, R., and Lemmen, C. (2006), Aspects of a 4D Cadastre: A First Exploration. In XXIII International FIG congress, Munich, October 2006..

Ostrom, Elinor (1990). Governing the Commons. The Evolution of Institutions for Collective Action, Cambridge University Press, p. 104-125.

Coca-Cola case in Kerala, India;
htttp://opencim.grenoble-em.com/mod/resource/view.php?id=1172

Right to Water Info; Case against Coca-Cola Kerala State: India; http://www.righttowater.info/ways-to-influence/legal-approaches/case-against-coca-cola-kerala-state-india/

Simpson, S. Rowton (1984). Land Law and Registration. Book 2: The Law. Cambridge University Press

Zhu Tianduowa (2009). Integrated Water Resources Management Based on Water Right Institution, A case study in Jinghui Irrigation District, Northwestern, China, MSc thesis, ITC/Chang'An University, March 2009.

BIOGRAPHICAL NOTES

Tarun Ghawana has an M.Sc in GIS with specialization in natural resource management from International Institute of Geoinformation Science and Earth Observation, The Netherlands. He has executed assignments as a GIS expert in India, Netherlands and Germany on natural resources management projects with academic as well as private consultancies. His area of expertise includes spatial analysis and spatial data modeling in particular for natural resource applications. He was involved in Indian NSDI for Department of Science and Technology, India. Currently, he is working as GIS Consultant with Integrated Spatial Analytics Consultants, a multidisciplinary firm which is based in India.

João Paulo Hespanha holds a MSc in Integrated Geoinformation Production of the International Institute of Geo-Information Science and Earth Observation (ITC) in Enschede (The Netherlands). From 1997 he is an adjunct professor at the Technology and Management Polytechnic School of Águeda, University of Aveiro, Portugal. He has been involved in lecturing and research projects on Cadastre since adoption of project-led education in 2001. From 2004 to the present date he is doing research on modeling in the cadastral domain at Delft University of Technology (OTB institute).

Jaap Zevenbergen is professor in land administration systems at the University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), department of Urban and Region Planning and Geoinformation Management in Enschede - The Netherlands. He holds Master degrees in geodetic engineering and law and defended his PhD on systems of land registration in 2002. He has published several articles and numerous papers about land administration and land registration. He has studied numerous systems of land registration, both as a researcher and as a consultant, the most recent being Ethiopia and Ghana. He is also a co-chair of Commission 7 Working Group 2 (with David Mitchell).

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, The Netherlands. In 1990 he received a PhD from Leiden University for this thesis ‘Reactive Data Structures for GIS’. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague, The Netherlands as a computer scientist. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, were he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology (OTB institute) and head of the section ‘GIS Technology’. He is the current chair of the FIG joint commission 3 and 7 working group on ‘3D-Cadastres’ (2010-2014).

CONTACTS

Tarun Ghawana
Integrated Spatial Analytics Consultants
A-201, Kairali Apts., Sector-3, Dwarka, New Delhi-110075
INDIA
Tel: +91-9958117758
Email: tarungh@gmail.com

João Paulo Hespanha
University of Aveiro, Escola Superior de Tecnologia e Gestão de Águeda
Rua Comandante Pinho e Freitas, n.º 28
3750-127 Águeda
PORTUGAL
Tel. +351 234 611500
Fax +351 234 611540
Email: jphespanha@ua.pt
Web site: http://www.ua.pt/estga/

Jaap Zevenbergen
University of Twente. Faculty of Geo-Information Science and Earth Observation (ITC)
P.O. Box 217
7500 AE Enschede
THE NETHERLANDS
E-mail: zevenbergen@itc.nl
Website: www.itc.nl

Peter van Oosterom
Delft University of Technology
OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel. +31 15 2786950
Fax +31 15 2784422
E-mail: P.J.M.vanOosterom@tudelft.nl
Website: http://www.gdmc.nl