**Towards a Methodology for the Assessment of Internationally Shared Aquifers**

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The issue of shared international waters is as old as the national borders that make those waters international. During the last century, a significant progress has been made in regulation of joint management of surface watercourses; many international river-, lake- or basin commissions have been set up and the legal treaties signed. Although some of these activities address "a groundwater component" as well, major comparable efforts related to the invisible groundwater have started just a several years ago.

Much can be learned from the surface-water experiences with respect to socio-economical, legal, and institutional aspect of international water management. Moreover, when surface and groundwater are hydraulically connected, an integrated (water resources) management should be exercised. However, the assessment of groundwater is – comparing with surface water - much more demanding and less certain. This paper discusses the assessment of internationally shared groundwater in an attempt to further clarify the assessment specifics and to elaborate the procedure to be followed.

The assessment needs to include all relevant aspects or facets of transboundary groundwaters. ISARM framework document (UNESCO, 2001) distinguishes five aspects of the transboundary aquifers, namely hydrogeological, legal, socio-economical, institutional and environmental. In the document, development of guidelines for each of the aspects listed above was suggested. In meantime, the only substantial progress (in preparing the guidelines) has been made by developing a legal instrument (draft articles on the law of transboundary aquifers). Numerous activities (particularly GEF projects and ISARM inventories) conducted in the last couple of years have yielded precious information on particularly hydrogeological and institutional aspects of transboundary aquifers. Yet, there are still no guidelines developed to assist these activities, nor an agreed overall methodology for assessment.

The original ISARM suggestion of having a separate guideline for each aspect of transboundary aquifers was apparently very ambitious. Besides, there is a strong link among the various aspects in practice. Assessment of transboundary aquifers is often mostly limited to the assessment of their hydrogeological situation, but if properly conducted it should incorporate also sufficient information on other aspects of transboundary aquifers. This should be reflected in the assessment procedure as well; it should guide the user through the assessment steps, pointing out the specifics of various aquifer aspects in the international context.

The assessment of the shared groundwater could be seen as composed of the following steps:

- Delineation and description
- Classification, diagnostic analysis and zoning
- Data harmonisation and information management

The first two activities (delineation and description) could be clustered as 'inventory' or 'characterisation', depending on the stage and the scale of activities. In any case, delineation and description are chiefly about collecting, combining and interpreting the field information.

The second set of activities provides the stakeholders with information necessary for decision-making, such as on problems that may develop and opportunities that will be forgone in the absence of coordinated groundwater resources development and management. Further on, the stakeholders need to know which aquifers are likely to be most the responsive ones to transboundary aquifer management, and which zones within such aquifers should be targeted for highest positive impacts.

One could argue whether the activities mentioned in the third step should be addressed separately; data harmonisation takes place in the previous steps and the information management is a management measure. Nevertheless, data harmonisation and information management have an additional dimension and importance in the international content; they are more difficult to carry out, more elaborated and politically sensitive. At the same time, they are also an opportunity for building trust and mutual understanding among the involved parties.

The following paragraphs contain a brief description of the basic assessment steps.

*Delineation*
Delineation of aquifer geometry (lateral extent and depth) is the most essential and usually the most difficult part of the assessment. An aquifer may be formed by an alluvial strip along a river, a single hard rock formation or a complex of various hydraulically interconnected formations. Though the regional hydrogeological settings are usually known and approximate boundary of aquifers might be shown on existing hydrogeological maps, information on exact boundaries of transboundary aquifers is often lacking. For the sharing countries a question may arise: can we delineate the aquifers and if yes, to what level of detail this information should be shared with other parties? The full paper will present an overview of several concepts of delineation as encountered in on-going transboundary initiatives (from lines through circles to detailed delineation).

*Description*
Once the lateral extent and thickness of a transboundary aquifer is defined (or approximated), its main properties have to be described. Recharge/discharge mechanism and hydraulic properties of aquifer are needed to determine direction and velocity of groundwater flow and its interaction with other water bodies (rivers, lakes, seas). These characteristics are also necessary to assess aquifer's vulnerability to overexploitation and pollution. Superimposed on these hydrogeological characteristics are the anthropologic influences such as abstraction and pollution from various sources. The full paper evaluates the current status of transboundary aquifer descriptions in various transboundary projects. It shows that general lack of data, the main bottleneck of any aquifer description, can be tackled by proper design of inventory forms (clear formulation of data type, units etc.) and by use of proxy information from various sources. An example of a comprehensive inventory form is given at http://igrac.nitg.tno.nl/sadc2.html.

*Classification*
Classification is simplification, but intended to deepen knowledge by revealing patterns, by highlighting certain features and/or by facilitating comparison between objects. In the case of aquifers, it allows comparing a specific aquifer with other ones, from a certain angle of view. Many angles of view can be chosen, depending on available information and the context of the analysis. Examples of angles of view for classification that may be relevant in the context of transboundary aquifer management are: aquifer size and hydraulic properties, vulnerability, current functions, observed or perceived stresses, need for transboundary aquifer management etc.

*Diagnostic analysis*
This step is interfacing assessment with transboundary aquifer management planning. Diagnostic analysis can be carried out in the first place as a screening step at the regional level, covering a certain number of transboundary aquifers. Its objective is ranking the inventoried transboundary aquifers according to criteria related to priority for transboundary management and so helping water resources managers in their judgment on which ones to select for inclusion in the transboundary action planning.

Transboundary diagnostic analysis (TDA) can also be applied to a single transboundary aquifer system, in analogy to TDA applied to lakes, inland seas and river basins. Published TDA results in the surface water domain usually contain the following elements: (i) inventory of major perceived issues and problems; (ii) overview of possible actions in response to the perceived

issues and problems; (iii) details on the main proposed actions and related aspects (stakeholders, institutions, expected impacts, etc.). No significant experience is available yet of TDA application to groundwater systems, but it is expected that a similar approach can be used successfully. After concluding TDA, a strategic action plan (STAP) can be developed.

*Zoning*
It can be observed that in groundwater systems, much more than in surface water systems, current and potential transboundary effects vary enormously within the aerial extent of the delineated system. As a result, often only a minor part of a large transboundary aquifer is relevant for controlling transboundary interactions. This is due to inherent inertia of groundwater systems and the usual fragmentation of groundwater flow into separate flow domains. Transboundary aquifer management should focus only on those parts of the aquifer systems that are likely to cause or receive transboundary impacts within a reasonable time frame. Dividing the aquifer into a number of zones may be helpful to do so. The zoning methodology should take into account – among others – the hydraulic characteristics of the aquifers (e.g. contrasting karstic versus weathered bedrock aquifers), flow direction and the type of transboundary interaction expected.

*Data harmonisation and information management*
The success of the characterisation of any aquifer relies heavily on availability and quality of related data. For the internationally shared aquifers, however, the harmonisation of data across the border plays an equally important role; if two data sets cannot be mutually compared (and further processed), they are not much of use. Besides, these data need to be made accessible internationally, which brings up the issue of information management.

Essentially, data harmonisation and information management are technical activities related to harmonisation of formats, classifications, terminologies, reference systems and reference levels, software and hardware specifics, etc. Yet, they are very much determined by political, organisational, legal, cultural and economical situation and agenda. A (lack of) progress made in harmonisation and common information management is often a reflection of political willingness to cooperate, but also of other differences (such as technical and organizational). Finally, the complexity of data is also the major factor: harmonisation of hydrogeological maps is, for example, far more complex than one of groundwater levels.

Alike the previously described assessment steps, data harmonisation and information management are carried out at various levels, the level being largely defined by current data availability and ambitions of involved countries. Many countries exchange and harmonize data ad hoc, for the purpose and duration of (mostly common) projects in border regions. This small-scale collaboration usually works, however inefficiently and without structural contribution to (common) information management.

In several GEF groundwater projects, relative simple databases have been developed to accommodate data of basic groundwater variables. Usually, a GIS is used for visualization of the maps and spatial variability of groundwater variables. No cases have been reported of harmonisation going beyond items such as reference levels and measurement scales. Equally, developed databases or systems are (according to the available information) neither web-based, nor real-time (i.e. automatically updated from the field). Databases available via IGRAC and INWEB portals contain meta information on transboundary aquifers. Water Information System Europe (WISE) accommodates delineated ‘groundwater bodies’ and the observations (with rather low density and frequency) of a selected set of groundwater variables. Ideally, all the transboundary data should be harmonised and made available on-line and real-time. The full paper will present such an information system, developed for the border region of Germany and the Netherlands.

The full paper elaborates also on other assessment aspects and tries to incorporate all of the steps in an overall procedure or methodology. It is hoped that this will contribute positively to the assessment of internationally shared aquifers in practice.