HYDROSCIENCE FOR FINDINGS OF FACT

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Summary

Surface water and groundwater science contribute to the fact-finding process by explaining past conditions and projecting future conditions in terms of causes and effects that impact water rights and damages. Each water management operation affects certain sources of water with impacts to be accounted for at the time of permitting, adjudication, or administrative control. New techniques of remote sensing and modeling are becoming available for water accounting and impact assessment that aid the fact-finding process.

Sources of Water

The old idea was that groundwater was a source and surface water was a separate source of water. A water right applied to a source, and if a diversion point dried up, the owner could "chase" the lost water to its source in the ground or upstream. The latest 2005, New Mexico Surface Water Regulations retain those categories. Law still trumps science.

Baseflow, the dry-day flow of streams, springs and wetlands represents aquifer discharge and illustrates that the distinction of surface and groundwater bodies has a time factor. The corpus of water in the stream today may have been in the groundwater body yesterday, and can seep back and forth tomorrow, subject to natural operations or to managed operations.

The more meaningful hydrologist's categories are flowing water and stored water; flowing in the stream or the aquifer, or stored in a surface reservoir or an aquifer reservoir. The terms "flowing" and "stored" reflect attributes of function and service from the resource. Flowing waters are renewable and stored waters are a stock resource. Of course, there is a little of the other attribute in each category.

The effects of a water management action of interest to others entail a change in prevailing expectations for their flowing or stored sources of water. Of course, the idea of an effect involves a change in prevailing conditions, not whether conditions are dry or wet, flowing high or low or whether a reservoir or aquifer is full or empty, but the difference that a proposed water operation makes to those baseline conditions.

In a stream, the effects of a new diversion are transmitted relatively quickly downstream at a rate of tens of miles per day, so that impacts on other users may be readily accounted for by observation or calculation.

An aquifer responds more slowly to change. In an aquifer, the response to a new pumping well falls initially on the aquifer storage as reflected in a growing area of water level decline, that is called the area of influence or cone of depression. At later times, the area of influence commonly expands to reach a stream, spring, wetland or other shallow water zone, where surface water and associated ecology can be affected. “Capture” is the hydrologist’s term for a well taking water from a surface water feature. A well produces water derived from complementary fractions of a large amount of aquifer storage and small amount of stream capture early in the well production cycle, and transitioning to a small amount of aquifer storage and a large amount of surface capture late in the well production cycle. Accordingly, neighboring well users are impacted early, and neighboring surface water users and ecology are impacted late in the well production cycle. The slow-growing impact of wellfields on surface water, once obscure, is becoming more obvious to all observers.

The surface capture account is increasingly being broken down into sub-accounts of impact on evapotranspiration, soil moisture, springs, interrupted tributaries, and selected features of ecological concern, in addition to water rights. Collateral drawdown transmitted via an interrupted stream to a location miles away from the center of pumping, is relatively common in mountain-front stream settings.

With the more comprehensive accounting being undertaken, it is apparent that wellfield withdrawals are ultimately balanced by varying degrees of capture from rivers, riparian vegetation, bare soil losses, soil moisture sources away from rivers, return flows and water inadvertently released to the ground at urban areas. In many cases the river depletion impacting other permitted uses is less than half of the wellfield source of water. Unmanaged sources of water may be the majority of the source to wellfields. Accordingly, ecological and other unmanaged effects, beyond permitted water rights, require an increased degree of attention.

Groundwater wellfields prove to be sustainable because they ultimately derive water from surface sources, but the surface impacts must be managed to be acceptable. Ecological and existing uses have to be planned. This is the idea of the European Water Directive, under which some major existing uses including public water supply, are being curtailed to protect “good status” of ecological waters.

New Model Capability

On the stored groundwater side of the question of effects, the issue is impairment of existing well rights. The specific meaning of impairment is one of administrative discretion, but is related to the idea of a loss of expectations for water supply, or damage as the economic cost imposed to make up for the changed conditions caused by the new use. The parameter indicating well impairment is an imposed change in pumping water level (PWL) in existing wells and any associated reduced yield or service life.

The grey area is where existing wells are old or unsound in construction such that they have no reasonable expectations of a long-term future service life. Many existing wells fall in that category. Whether or not an imposed change in PWL from a new properly constructed well can be found to be impairment in that case is up in the air.

Nevertheless, the hydrologist's function is to describe the initial and the changed conditions for the decisions maker's action. A new tool of leading importance has become available, the Multi-Node Well Package, (Halford and Hanson, 2002).

The MODFLOW model by the U.S. Geological Survey[1] is well established as an evidentiary program for calculating aquifer and stream interactions. It has been accepted since the 1980's in Federal Court, State Court, and administrative hearings. An issue often arises about the model cell-based (model cells are of large dimension relative to a well diameter) output, and how it can be converted to a PWL. That could not be done inside the program, but was adapted by various means externally, until the Multi-Node Well (MNW) package was published.

The MNW package organizes the valuable additional information for impairment analysis in a set of consistent specifications for converting model-node head to well PWL

[1] Harbaugh, A.W., 2005, MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model—The Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.

and reduced yield, if any. The terms to be considered are aquifer losses from the model grid node to the well, a well efficiency term for losses from the aquifer to the well center, and a non-linear turbulent flow loss representing the inefficient hydraulics of the well screen, gravel or pipe. A threshold of lowest practical PWL without affecting yield can be assigned to each well. These parameters can be specified from well tests or from assumed performance of properly constructed wells. Each well with known or assumed depth and screen intervals in the area of influence of a new project can be evaluated inside the MODFLOW program. Uniformity of output at dozens or hundreds of wells can be achieved as to reasonable impact on PWL and yield. The critical information required for judging impairment, missing in our former models, is readily available in MODFLOW with the MNW package.

As the capabilities of the MNW package become more widely recognized, we can expect that it will be a staple requirement of well impact assessment for water right purposes.

Remote Sensing

The scientific accounting of water benefits from advances in processing satellite data on vegetation brightness (NDVI)[2] and temperature of the land surface. Satellite data can be used to show relative strength of evapotranspiration throughout an image area, or can be tied to land stations to derive quantity of evapotranspiration losses. Each pixel of the LANDSAT satellite image covers 0.25 acres reported every 16 days for high-resolution information on the scale of farm fields. Crop inventories are not needed, because temperature and vegetative indexes show actual performance of each field, including bare soil, riparian, idle or abandoned fields, and free-water surface losses.

SEBAL[3], METRIC[4], and CRAE[5] illustrate the several approaches to basin-wide quantification of evapotranspiration losses at high resolution. These approaches will become increasingly important to managing such water loss once we recognize where losses occur and at what rate. A GIS data model for spatial water budgets has been published[6].

For example, it is clear that cottonwood and tamarisk fields have a spectrum of loss rates depending on many factors other than vegetative species (water table depth, distance from surface water, soil type, etc.). There is no single crop coefficient or loss rate that can be applied to all sites of a vegetation type or species.

A further realization of fundamental importance is that the consumptive use (CU) rate that is the conventional measure of a water right is not the net amount consumed with

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[2] Rouse, J.W., Haas, R.H., Schell, J.A. and Deering, D.W., 1973, Monitoring Vegetation Systems in the Great Plains with ERTS. Third ERTS Symposium, NASA SP-351 I:309-317.

[3] Bastiaanssen, W.G.M., Menenti, M., Feddes, R.A. and Holtslag, A.A.M., 1998a, A Remote Sensing Surface Energy Balance Algorithm for Land (SEBAL): J. Hydrology, 212-213, p. 198-212.

[4] Allen, R.G., Tasumi, M. and Morse, A., 2005, Satellite-Based Evapotranspiration by METRIC and LANDSAT for Western States Water Management.

[5] Morton, F.I., 1983, Operational Estimates of Areal Evapotranspiration and their Significance to the Science and Practice of Hydrology: Journal of Hydrology, 66:1-76.

[6] http://www.balleau.com/materials/BGW_NMWRS2005.pdf.

and without irrigation. Half or more of the CU persists in the shallow water floodplain, even after the water right is transferred to a new place and purpose. The January 2005 New Mexico Surface Water Regulation (19.26.2.7 NMAC) puts new attention on the issue by defining the “allowable consumptive use allocation” for transfer as excluding “water that is not beneficially consumed in the course of water use”. We can expect that the practice of transferring CU will be re-examined in the future, and a smaller net amount might become the standard for transfer.

The new modeling and inventory methods are rapidly becoming established in water science practice and can be expected to serve as evidence in increasing number of cases.

Conclusions

1. Hydroscience has a fundamental role in fact finding for water law issues.

2. Causal models are necessary that explain and link stresses to responses of concern.

3. The hydrologic responses of concern to the legal process are expanding from the simple aquifer to stream impact into ecological, soil moisture, and land use topics that require new tools for evaluation. Those tools need to be well established in the science to have evidentiary value, and are rapidly being adopted.

4. The issue of well impairment hinges on the status of PWL with respect to well construction and a safe margin of water column for expected future service life. A recent MNW package in MODFLOW addresses those issues.

5. Basin-wide water accounting by remote-sensing of surface temperature and vegetative reflectance is advancing our ideas of crop water loss and management objectives.