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A guide to integrated water management in Nebraska

New Water Use Offset Calculation

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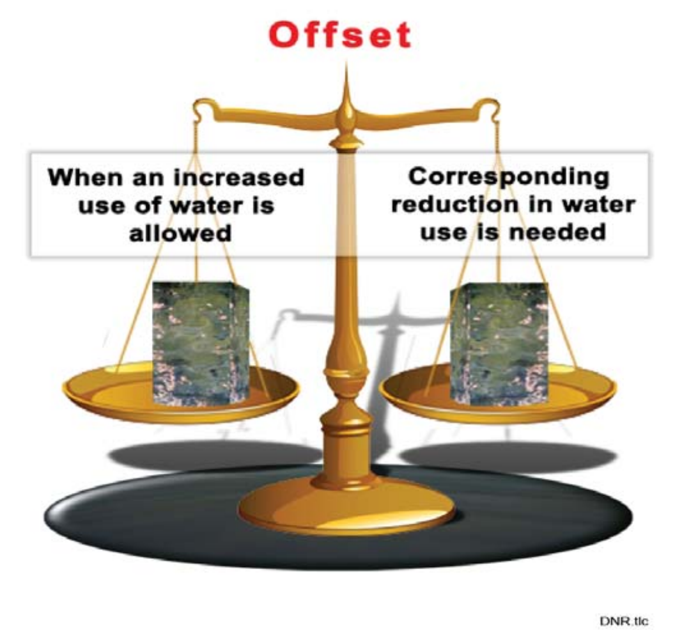
While the information presented in this article is technical in nature, it has been generalized to appeal to a broader audience. This article provides an overview of a very complex topic. The DNR is currently collaborating with other entities to produce more in-depth analyses and information.

Introduction

The Nebraska Groundwater Management and Protection Act provides that during the integrated management planning process, an overall goal is to balance water supplies, uses, and the near and long-term economic viability of the basin. A powerful mechanism by which water managers can employ best management practices with respect to new uses of water is the concept of an offset: that each new use is "offset" by a corresponding reduction in consumptive use of water. A "new use," for the purposes of this document, can be defined as any change in water use whose effects on streamflow cause depletions not previously realized. Employing the offset control mechanism provides managers with a methodology that can be used to evaluate effects of individual new uses and offsets, as well as to monitor the cumulative effects across an entire district or basin.



This document will describe in general terms, the factors that must be considered and/or calculated for the purpose of mitigating, or offsetting, a new use of water. It is not intended as an instructional "how to;" rather, it is an explanatory description of the calculation process only. For the purposes of this analysis, harm to existing users is assumed, since impacts to streamflow are well documented and existing users are dependent on streamflow and recharge derived from streamflow. Existing tools do not currently have the ability to account for timing of streamflow effects, as those effects are typically realized over days to weeks, whereas existing tools analyze streamflow annually or seasonally.

Approach

There are three critical concerns that must be considered when conducting a calculation for the purpose of offsetting a new use; they include quantity, location, and timing. The quantity, for the purpose of these calculations, represents the volume of water removed from, or added to the groundwater system by the new use. The location term denotes the desired new use and offset use locations as defined by the individual or agency requesting the new use. The timing term relates to when, or how quickly, streamflow may be affected, and is typically defined as the cumulative reduction to the groundwater component of streamflow as a percentage of the volume of groundwater removed.

The water use term must be calculated four times: the before condition (initial use) as well as the after condition (proposed new use) at the proposed new use and offset locations. Stream depletion factors (percentage of cumulative pumping for 50 years) must be calculated for the respective locations, and a confidence factor must be estimated to account for quantitative and qualitative uncertainties in estimation of parameters and measurements. The water use calculations address the quantity concerns noted above. The stream depletion factor calculations incorporate the location and timing concerns and can be estimated through analytical (Jenkins, 1968, Hunt, 1999) or numerical methods (COHYST, 2004). A confidence factor represents an adjustment to the basic calculation for the purpose of mitigating risk and incorporating conceptual limitations of the proposed methodology.

Estimating consumptive use

There are a number of scale-dependent methods available to estimate consumptive use of crops, various non-crop vegetative covers, and open water surfaces. These include: lysimeter, sap flow measurement, pan evaporation, diurnal water table fluctuation, water budget, remote sensing, energy balance, mass transfer approximation, and physically and empirically based equations. They require varying levels of detailed measurement and have methodology-specific limitations, indicating that appropriateness must be determined on a case-by-case basis. If multiple methods may be acceptable for a given location, an analysis of the most reliable method under the given conditions must be conducted.

At present, two public domain models exist, which aid individuals in quickly and easily estimating new uses and potential offsets: the NRCS Consumptive Use Calculator (2001) for the Platte River Watershed, which uses the Blaney-Criddle method (an empirical, temperature-based ET model); and the Central Platte NRD online offset calculator, which uses the soil moisture balance model CROPSIM in conjunction with COHYST groundwater model calculations under 1997 climactic conditions (http://dnrmap2.dnr.ne.gov/CIR/Offset.asp).

Calculation

The spatial relationship between the new use and offset locations may have significant impact on the calculations and is site specific. The calculation is simplified if the new use and offset locations can be chosen in such a way as to minimize the effects of location and timing. The location and timing terms are incorporated into the calculation through the use of numerical or analytical models of the areas in question. Often, the long-term average (50 year) depletion percentage is the term that will be used to account for the location and timing issues. Long-term use changes will continue to have effects well beyond 50 years. Short-term (temporary) changes may or may not have significant effects beyond 50 years. In terms of quantity, an offset calculation can be expressed as follows:

$$\Delta N + \Delta O \leq 0 \tag{1}$$

Where:
ΔN = new use
ΔO = offset use

And the new and offset uses are defined as:

$$\Delta N = N_p - N_i \tag{2}$$

$$\Delta O = O_e - O_i \tag{3}$$

Where:
N_i = initial use at new use location
N_p = proposed new use

O_i = initial use at offset location
O_e = ending offset location water use

And:
$N_p > N_i$
$O_e < O_i$

Incorporating the stream depletion percentage applied to the new and offset use terms accounts for the location and timing terms, assuming long-term (50 year) average is reasonable. Substituting the stream depletion factors, equation (2), and equation (3), as well as a confidence factor (C) into equation (1) yields:

$$sdf_N (N_p - N_i) + C (sdf_O (O_e - O_i)) \leq 0 \quad (4)$$

Where:
sdf_N = stream depletion factor at the new use location as a percentage of cumulative volume pumped (calculated by analytical or numerical model)
sdf_O = stream depletion factor at the offset use location as a percentage of cumulative volume pumped (calculated by analytical or numerical model)
C = confidence factor (percent, represented as the decimal equivalent)

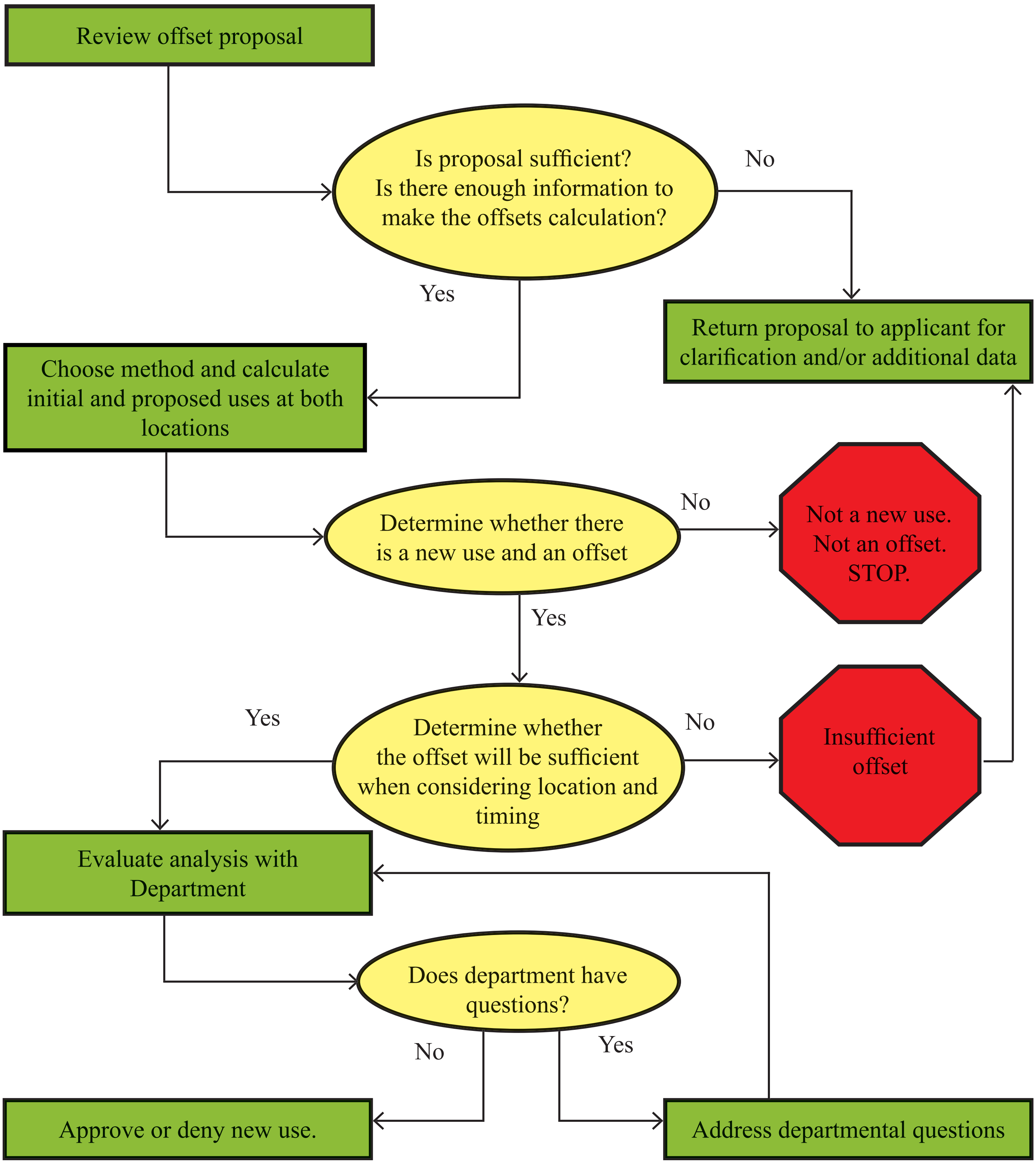
The requirement defined in equation (1) is that the sum of the new and offset uses is less than or equal to zero. This requirement results from the convention that the proposed new use (ΔN) is positive and the offset use (ΔO) is negative. Accordingly, equations (2) and (3) define the before and after conditions at the proposed new use and offset locations such that this requirement is satisfied. Thus, assuming 100 percent confidence (C = 1.00), when the offset use (ΔO) is greater in magnitude than the proposed new use (ΔN), the result of the summation will be negative. Under the circumstance that the proposed new and offset uses are equal in magnitude, the result will be equal to zero. The magnitude of any negative result from equation (4) represents the amount of offset use in excess of the new use, and is therefore an addition to the groundwater system capable of being used as an offset for an additional new use of groundwater.

The confidence factor (C) is a mechanism by which an offset calculation can be adjusted to mitigate risks associated with uncertainties present when determining the components of equation (4). This factor can be estimated through quantitative and/or qualitative uncertainty analysis. A quantitative numerical uncertainty analysis will result in some confidence less than 100 percent that represents simple calculation uncertainties associated with the various methods and models employed to develop values for equation (4). This quantitative value would then represent a hypothetical maximum confidence factor which could then be further reduced by qualitative assessment of the manager relating to risks, costs, and social or economic factors associated with a particular offset. Qualitative analysis may also substitute for quantitative analysis in the absence of a formal quantitative uncertainty assessment

Assumptions

- Measurement and/or modeling of streamflow, or the groundwater component of streamflow, is the most sensitive available mechanism to assess water supply and subsequent impacts to water supply from new uses and offsets.
- Water for a new use is introduced in these calculations only in an amount sufficient to supply the net increased water use requirement (the net increase in consumptive use).
- Differences in irrigation requirement estimation methodologies have uncertainties consistent with uncertainties relating to measurement and modeling of streamflow and its groundwater-derived component.
- A 50-year numerical modeling analysis is sufficient to determine long-term stream depletion as a percentage of pumping and is reasonably representative of the likely impacts in a typical year independent of the rate at which pumping is conducted.
- Prior land use on all acres in question is certified either through the natural resources district certification process or by surface water appropriation.
- The proposed new use and offset areas are minimally affected by sub-irrigation. In the event they are quantifiably affected, separate detailed analyses are required.
- Non-permanent or short-term new uses requiring seasonal or year-to-year accounting mandate additional case-by-case analysis not described in this document.
- Both the proposed new and offset uses are supplied from groundwater.
- Surface water appropriation transfer, or retirement, introduces complicating factors in offset calculations requiring more detailed analysis than outlined here.
- In fully and overappropriated basins, any new use of water will impact existing users on time scales appropriate for analysis with existing models. Existing tools (including models) must be redeveloped to analyze impacts on timescales finer than multiple years to decades.

Recommended Workflow for Evaluation of Offsets



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An article entitled, "What Is An Offset?" appeared in the November 2008 edition of the DNR's newsletter. While that article offered an introduction to the concept of an offset, this article provides further discussion of how offsets work. The newsletter is available at http://www.dnr.ne.gov/dnrnews/newsarchive2.html.

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Please contact the Nebraska Department of Natural Resources with questions or concerns about this publication at 471-2900.

Visit the Integrated Water Management Division's website at http://www.dnr.state.ne.us/LB962/LB962Implementation.html for up-to-date information. *Water Matters* will soon be available at this website.