MEMORANDUM

To: Anders Hauge, HBA
Robin Cort, Parsons ESA
Linda Stone, Parsons ESA

From: Jeffrey Peters, Questa Engineering
Norman Hantzsche, Questa Engineering

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Subject: Irrigation Nitrogen Loading to Groundwater, West County and South County Reclamation Alternatives

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A simplified procedure for estimating the allowable hydraulic loading (irrigation application) rate for applying reclaimed water containing nitrogen to cropland so that the percolate or leachate (Cp) does not exceed a prescribed 10 mg/l N annually was presented in *EPA Process Design Manual for Land Treatment of Municipal Water* (EPA 1981). The equation assumes an uptake/utilization rate of nitrate by the growing crop (all N is converted to nitrate) as well as N loss by volatilization and dentrification during and following sprinkler application.

The equation is of the form:

$$Lwn = \frac{(Cp)\,(P\text{-}ET) + U\,(4.4)}{(\,(1\text{-}f)\,(Cn)\,) - Cp} \qquad (1)$$

Where:

Lwn	=	hydraulic loading (irrigation application rate for irrigated pasture, in inches/year)
Cp	=	nitrate concentration in water after percolating through root zone (mg/l N - EPA suggests a permissible level of 10 mg/l)
P-ET	=	normal year, precipitation-evapotranspiration
U	=	nitrogen uptake by crop (irrigated pasture)(lbs/acre-year)

Cn	=	nitrogen concentration in applied wastewater (after 20 percent reservoir losses from dentrification mg/l N). [1]
f	=	fraction of applied nitrogen removed by dentrification and volatilization (assume 0.2 per EPA guidelines)

The amount of reclaimed water that can be applied by sprinkler irrigation has been determined for various soils, crops and climatic situations (West and South County areas) based on procedures contained in Chapter 8 of *Irrigation with Reclaimed Municipal Wastewater, A Guidance Manual* (Pettygrove, S. and T. Asano, 1984). For irrigated pasture, and with an adjustment for an 80 percent irrigation efficiency, application rates are estimated to be 23 inches for the West County and 33.6 inches for the South County. The higher South County irrigation application rates are indicative of lower rainfall amounts and warmer summers.

Because of the relatively low N content of the wastewater, irrigation applications are dictated by crop and climatic considerations and not wastewater nitrogen, a system the above-referenced authors consider to be Type I for design purposes. Given an irrigation application rate, the EPA allowable hydraulic loading equation can be rearranged to solve for Cp (rather than specifying a 10 mg/l acceptable Cp percolate or leaching fraction). The Cp value provides an estimate of the quality of water passing through the root zone and reaching the underlying shallow zone aquifer. For large deep aquifers, the entering nitrogen-containing percolate will be greatly diluted by the water stored in the aquifer. Over a prolonged period of time (25+ years) and for shallow aquifers of limited storage capacity, annual irrigation applications of this reclaimed water quality will provide a conservative approximation of groundwater quality.

A more detailed procedure for estimating N groundwater quality loading for various crops is presented in the Technical Memorandum prepared by Professor Kenneth Tanji of U.C. Davis, which also evaluates and incorporates manure and fertilizer inputs, shallow and deep aquifer factors, and stream interactions. (*Water Quality Evaluations on Wastewater Irrigation in West County and South County Alternatives, Santa Rosa Long-Term Wastewater Project*, K. Tanji, 1995.) For groundwater, the Tanji model predicts N mass loading in "N lbs/100 acres" for various types of agricultural crops. Very low N mass loading to the deep aquifer is predicted in the Tanji model, typically less than one pound per 100 acres. The more simplified approach presented here allows an estimation of N concentration (in mg/l) in the percolate and thus predicts impacts to groundwater.

Rearranging the previous equation to solve for Cp:

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[1] Conservatively assumes 30-day reservoir detention. Based on above EPA process Design Manual formula:

$$N_t = N_o\, e^{-0.0075t}$$

where: N_t = nitrogen concentration in pond effluent (total N), mg/l
N_o = nitrogen concentration entering pond (total N), mg/l
t = detention time, d

$$Cp = \frac{(Cn)(Lwn)(1-f)-4.4U}{(P-ET)+Lwn} \quad (2)$$

Applying Equation 2 and the following input variables gives calculated Cp values for the West and South County areas, as shown below:

		West County	South County
Lwn	=	23"	33.6"
P-ET	=	28.3"-30.5"=-2.2"	24.0"-39.5" = -15.5"
U	=	60 lbs/acre	80 lbs/acre
Cn [2]	=	11.6 mg/l	11.6 mg/l
f	=	0.2	0.2
Calculated Cp		-2.38 mg/l	-2.27 mg/l

Since the Cp values are negative, this indicates that the irrigation application rates are conservative and in fact will not fully meet the nitrogen demands of irrigated pasture. Additional fertilizer (or animal manure) can be applied to meet crop demands as outlined in the Irrigation Management Plan. This would be based on soil testing with any fertilizer and manure application recommendations made by an agronomist provided by the City.

While the above analysis shows the crop demand for nitrogen is sufficient to utilize all of the applied nitrogen in the reclaimed wastewater, the EPA methodology includes two simplifying assumptions which are not likely to hold true for the proposed reclamation projects in either the West or South County. These assumptions are:

1. Zero Runoff. All precipitation goes to satisfy ET demand or percolates to become groundwater; none results in runoff; and,

2. 100% Nitrogen Uptake Efficiency. All available nitrogen in applied wastewater is utilized efficiently by the crop(s) up to the crop demand; and none migrates through the root zone to the underlying groundwater until the crop demand is satisfied.

For both the West and South County project areas, hydrologic studies (see *Baseline Hydrology and Irrigation Drainage Evaluation for West and South County Reclamation Alternatives*, Questa Engineering Corp., November 1995) indicate that as much as 40 percent of annual precipitation will leave as runoff, and not become part of the groundwater recharge. Also, it is not realistic to assume that all applied nitrogen will be utilized by the crops; a loss of 10 percent, due

[2] Santa Rosa reclaimed water nitrate levels are expected to be about 14.5 mg/l after the interim nitrogen removal system is constructed. Nitrogen losses in reservoir storage are conservatively estimated to be 20 percent or 11.6 mg/l reclaimed water N.

to referential flow in soil from over irrigation or other local anomalies, is a more reasonable assumption. This assumption is consistent with soil and hydrologic conditions in the West and South County study areas, the high irrigation application efficiency proposed (80 percent), and N loss studies reported in Follett, et al. (1991).

With these revised assumptions, the groundwater nitrate concentration resulting from the application of reclaimed water can be approximated by the following mass balance equation:

$$Cp = \frac{(Lwn)(Cn)(1-f)(1-E)}{Lwn + P(1-RO) - ET} \qquad (3)$$

Where:

RO = Annual runoff as a fraction of average annual precipitation
E = Efficiency of nitrogen uptake by crop (or pasture grass) as a fraction of the applied nitrogen in reclaimed water.

Utilizing estimated values of RO = 0.4 and E = 0.9, along with the previously cited input variables, the estimated Cp concentration for the West and South County areas according to Equation 3 is as follows:

West County:

$$Cp = \frac{(23)(11.6)(1-0.2)(1-0.9)}{23 + (28.3)(1-0.4) - 30.5}$$

$$Cp = \frac{21.3}{9.48} = 2.25 \text{ mg/l, as N}$$

South County:

$$Cp = \frac{(33.6)(11.6)(1-0.2)(1-0.9)}{33.6 + (24.0)(1-0.4) - 39.5}$$

$$Cp = \frac{31.18}{8.5} = 3.67 \text{ mg/l, as N}$$

These calculations show a measurable, but relatively low, nitrate-nitrogen effect on local groundwater in areas receiving reclaimed water. This is a more conservative (i.e, safe) analysis than that provided by the EPA methodology (Equations 1 and 2).

References:

Follett, R.F., D.R. Keeney and R.M. Cruse (1991). *Managing Nitrogen for Groundwater Quality and Farm Profitability*. Soil Science Society of American, Inc., Madison, WI.

Pettygrove, S. and T. Asano. July 1984. *Irrigation with Municipal Reclaimed Wastewater, is a Guidance Manual,* prepared by Department of Land, Air and Water Resources, University of California, Davis for California State Water Resources Control Board, Sacramento, CA, Report No. 84-1 WR.

U.S. Environmental Protection Agency (1981). *Process Design Manual for Land Treatment of Municipal Wastewater*. EPA 615/1-81-013, U.S. EPA. Cincinnati, Ohio.