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TETRA TECH

Memorandum

To:	**Cindy Potz (Yellow Medicine River Watershed District) and Mike Weckwerth (MPCA)**	**Date:**	**March 11, 2015**
From:	**Andrea Plevan**	**Subject:**	**Watershed Management Scenarios for Yellow Medicine River Watershed Restoration and Protection Strategy**
cc:	**Pete von Loewe, Jon Butcher**		

This memorandum transmits the results of the watershed management scenarios that were developed to support the Yellow Medicine River Watershed Restoration and Protection Strategy (WRAPS). The Yellow Medicine River watershed is located in west central Minnesota and includes the drainage from the Yellow Medicine River and its tributaries in addition to a few neighboring streams that flow directly into the Minnesota River. This area is collectively referred to as the Yellow Medicine River watershed and covers approximately 685 square miles. High concentrations of sediment, phosphorus, and nitrates are found in the water bodies, the sources of which include agriculture runoff, livestock manure, stormwater runoff, and failing septic systems. Much of the watershed is ditched and channelized or tiled, and high stream flows lead to stream bank erosion. The primary land use in the watershed is agriculture.

The WRAPS is the culmination of a 4-year process led by the Minnesota Pollution Control Agency and the Yellow Medicine River Watershed District to monitor the water quality in the watershed, assess the water bodies for impairment, develop total maximum daily loads (TMDLs) for the impaired water bodies, and prescribe strategies to restore and protect the water bodies. A model application was developed with the program Hydrological Simulation Program–FORTRAN (HSPF) that simulates flow and water quality in the Yellow Medicine River watershed on approximately a Hydrologic Unit Code 12 (HUC12) basis. For the current project, management scenarios using the HSPF model application were developed to inform management strategies that will be recommended through the WRAPS process.

The management scenarios to be modeled were determined through discussions with the Yellow Medicine River Watershed District, MPCA, and the WRAPS work group. The work group held a meeting on December 9, 2014 during which Tetra Tech staff explained the model inputs, outputs, level of resolution, and examples of management scenarios that can be developed using the model. The work group selected three scenarios, which are discussed in this memo.

1 Model Scenario Approach

Hawk Creek, Yellow Medicine River, and several adjacent tributaries to the Minnesota River constitute the 8-digit USGS Hydrologic Unit 07020004. MPCA is supporting development of detailed HSPF watershed models for all 8-digit HUCs throughout the state for management planning. Tetra Tech (2011) developed the detailed (HUC12-scale) HSPF model of the HUC8 containing Hawk Creek and Yellow Medicine River with meteorology set up to run through 2010. More recently, RESPEC (2014a, 2014b) completed an update of the existing models for the Minnesota River drainage. The original setup of the Hawk-Yellow Medicine model was largely retained, except that four reaches were modified to better represent defined impaired stream segments (RESPEC 2014a; see Figure 1). In addition, the model simulation period was extended through 2012 and the representation of point sources was improved. RESPEC (2014b) also undertook some adjustment to the model calibration based on additional monitoring data through 2012.

The model scenario simulations were undertaken with the latest version of the model, as updated by RESPEC and provided by MPCA. It should be noted that this version of the model is still under review by MPCA and it is possible that some aspects of the model calibration may be modified. Nonetheless, the current version of the model provides the best currently available tool for investigating the WRAPS scenarios.

The model represents upland land use in the basin through 24 different Hydrologic Response Units (HRUs). Each HRU combines an overlay of land use, hydrologic soil group (an index of infiltration capacity), and slope category. There are 12 agricultural land use categories representing conventional tillage, conservation tillage (defined as maintaining 30 percent residue cover), and manure application areas on different combinations of hydrologic soil group and soils. The landscape is dominated by tilled agriculture, primarily in corn/soy bean rotation (Figure 2). Agriculture on soils with dual hydrologic soil group classifications (e.g., B/D) is assumed to have tile drains installed, represented in HSPF through the interflow (shallow groundwater) component. There are no major point source discharges in the Yellow Medicine River drainage, although there are a number of small wastewater stabilization ponds that discharge seasonally.

The Yellow Medicine portion of the model achieved acceptable calibration and validation for flow at the continuous USGS stream gage for Yellow Medicine River near Granite Falls (USGS05313500) as well as the seasonal gage on Yellow Medicine River near Hanley Falls (DNR 25087001). The water quality model is fully calibrated and validated for sediment, inorganic nitrogen, total nitrogen, inorganic phosphorus, and total phosphorus. The model also simulates dissolved oxygen, biochemical oxygen demand, algal growth, and bacteria based on parameters derived from an earlier model; however, the current model has not been rigorously calibrated for these parameters.

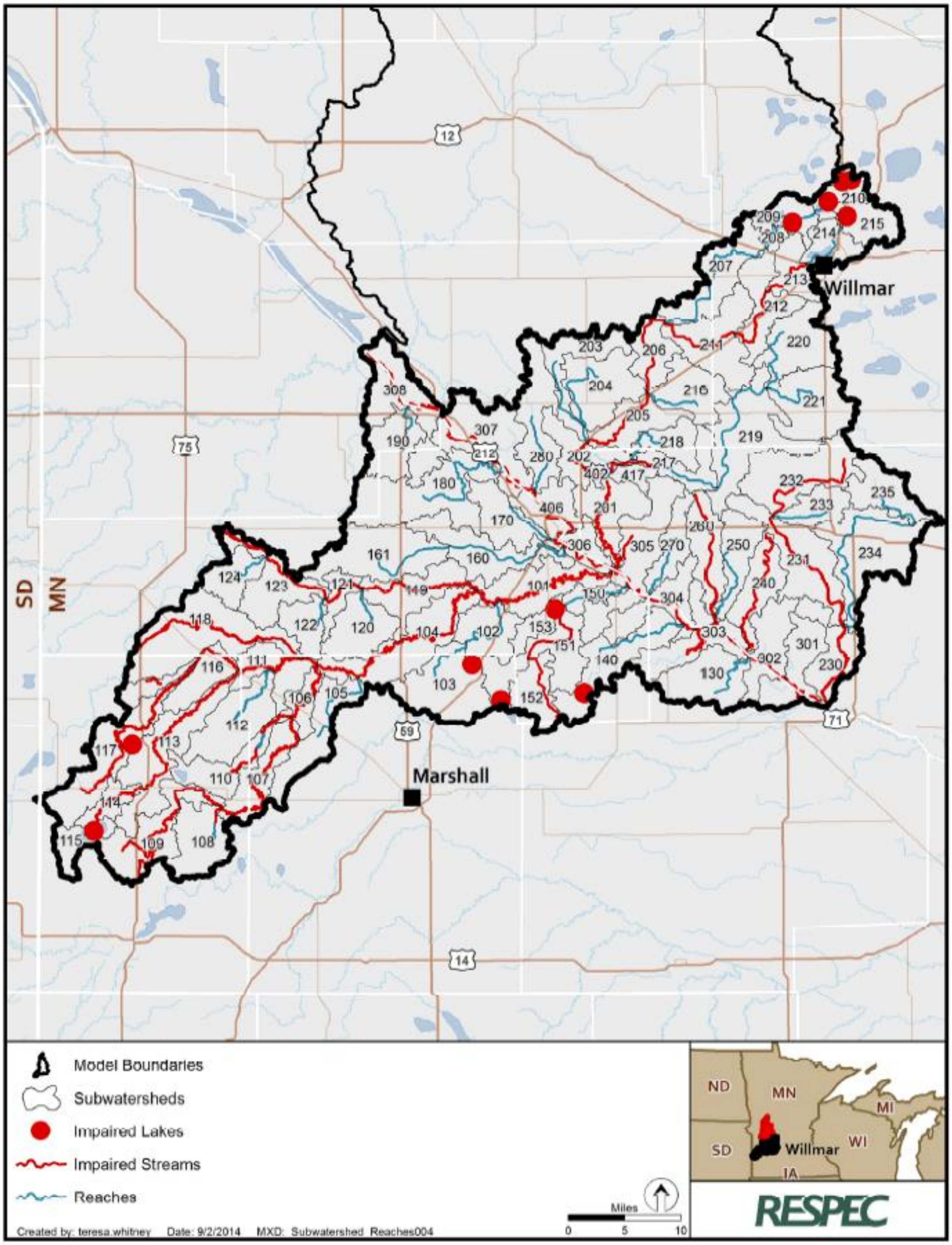

Figure 1. Hawk-Yellow Medicine model reach and subwatershed identifiers (RESPEC 2014a)

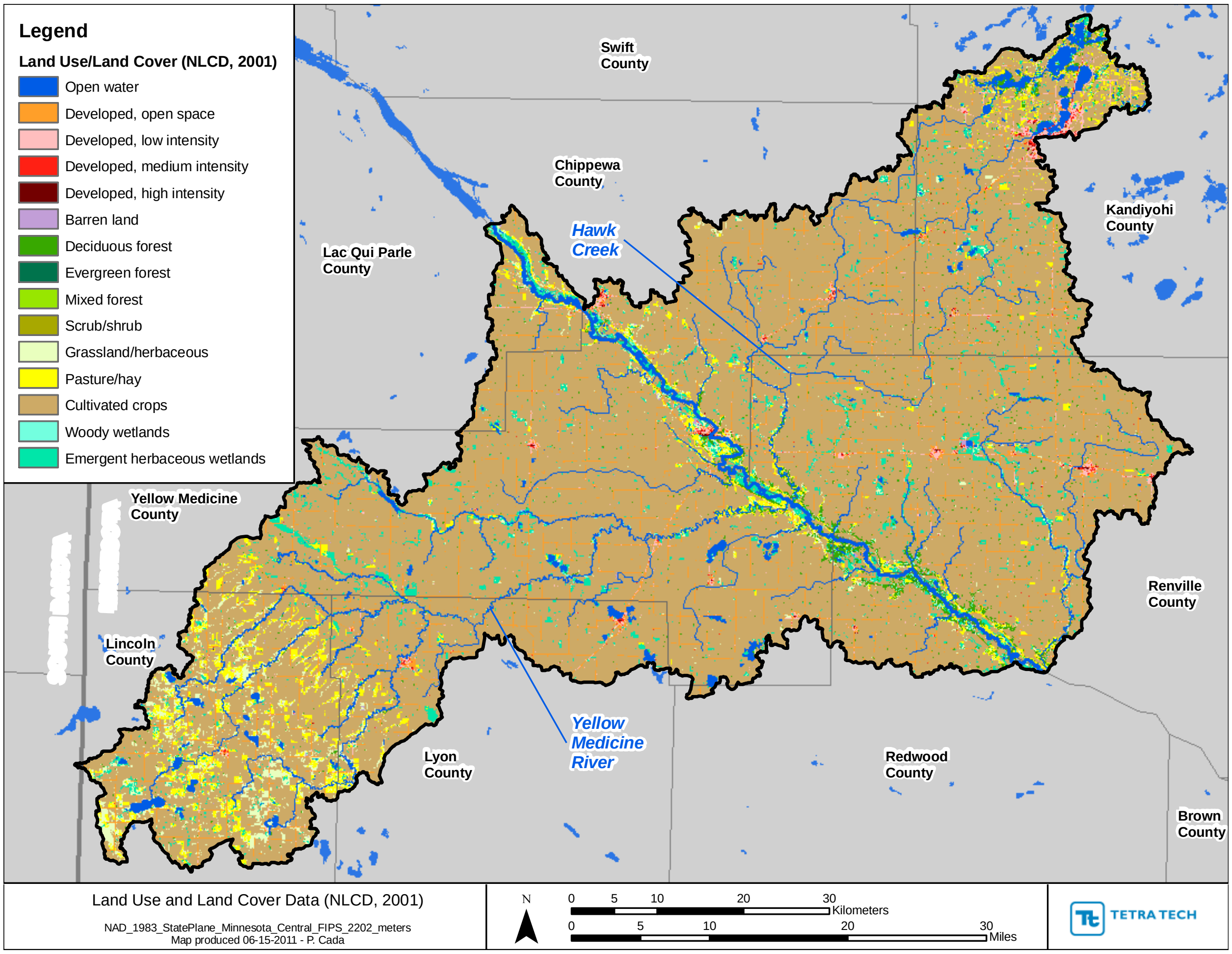

Figure 2. Land use/land cover in the Yellow Medicine/Hawk Creek basin

The following three scenarios were simulated in HSPF:

1) **Water and sediment control basins**. The model was modified to include explicit simulation of unit-area sedimentation basins that capture and hold 50 percent of the first two inches of runoff from agricultural lands. "Runoff" included surface runoff and shallow groundwater flow; tile drainage is captured in shallow groundwater flow. The captured flow is drained over a 48-hour period. Sediment and nutrient attenuation rates for flow entering the sedimentation basins were based on literature values. Specifically, the sedimentation basins were assumed to remove 80 percent of solids, 25 percent of inorganic phosphorus, and 30 percent of organic matter (including organic nitrogen and organic phosphorus) in the captured fraction of the first two inches of runoff based on typical performance of generic sedimentation basins (Novotny and Olem 1994). No reduction in inorganic nitrogen occurs, and no reduction is assigned to flows in excess of 2 inches that bypass the detention basin.

2) **Nutrient management and manure management**. Nitrogen and phosphorus load generation rates from agricultural lands were reduced to follow fertilization recommendations from the University of Minnesota and to be consistent with the projections in the Minnesota Nutrient Reduction Strategy (MPCA 2014). The setup for this scenario follows the approach described for the Minnesota River Basin by Tetra Tech (2009), in which reductions in fertilizer and manure application rates are interpreted to yield changes in the parameters controlling nutrient loads in the HSPF model. Typical fertilization rates on corn/soybean agriculture during the period of

model calibration are assumed to be as given in Mulla et al. (2001), Table 12a. Nitrogen application rates are, on average, reduced from 165 to 111 lb/ac/year, which results in a direct reduction in nitrogen losses. Phosphorus loads depend to a large extent on residual soil phosphorus, so the revised application rates are not directly informative. Instead, calculations are based on gradually reducing soil test phosphorus to 16, which yields a net reduction of 24 percent in phosphorus loading from the Yellow Medicine River relative to 2009 conditions based on the load estimation worksheets developed for the Nutrient Reduction Strategy (MPCA 2014). Manure application is adjusted to achieve agronomic rates for nitrogen, resulting in lower application rates on a larger application area. The calculated reductions for nitrogen and phosphorus are applied to the surface buildup rates and limits (for nitrate), the sediment potency factor for phosphorus (pounds of phosphorus per ton of sediment), the sediment potency factor for organic matter washoff, and the interflow and groundwater concentrations of inorganic nitrogen, inorganic phosphorus, and organic matter.

3) **Cover crops and riparian buffers**. For the cover crops component of this scenario, a 30 percent adoption rate of cover crops on the corn-soy rotation was simulated. This primarily affects the erosion cover in the fall and over-winter and is specified by adjusting the monthly cover factor, as described in Tetra Tech (2009). For the riparian buffer component of the scenario, 80 percent of stream reaches in the National Hydrography Dataset (NHD) high resolution flow lines data layer is assumed to have grassed buffers. Under current conditions, 70 percent of the stream miles are stated to have acceptable buffers (per discussions with MPCA staff), so this represents an increase of 10 percent in the extent of buffers. Because there is not a full spatial inventory of buffer status this was implemented by converting 80 percent of agricultural and barren land within 50 feet of stream lines to grassland. The buffer areas are assumed to be optimized to achieve treatment by limiting concentrated flow, which enables them to remove a proportion of the pollutants originating from upstream field areas. The amount of adjacent land treated by buffers and the associated pollutant removal is calculated by the same method as is used in the SWAT model (White and Arnold 2009). To simulate the water quality effects of the buffers on runoff from adjacent lands, pollutant removal rates developed for the 2011 Hawk Creek scenario (Tetra Tech 2011) were assumed (51 percent removal for sediment, 42 percent for organic nitrogen, 43 percent for inorganic nitrogen, 46 percent for sorbed and organic phosphorus, and 35 percent for dissolved phosphorus). The removal rates were adjusted to account for the fact that only 10 percent of the land receives new buffers; the effect of existing buffers is already implicitly incorporated in the model calibration. The weighted removal rate after adding new buffers to 10 percent of the land is 10% x R + 90% * (1 – O), where O is the original mass-link pass through factor for the baseline model.

2 Scenario Results

Scenario results can be generated for each segment in the watershed model. This memorandum focuses on the integrated results present near the mouth of the Yellow Medicine River (reach 201), which is the primary model calibration point. This location is purposefully selected as above the bluff area at the river's entry to the Minnesota River floodplain which contributes additional sediment loads that are not amenable to control by agricultural BMPs. Scenario results are presented for the baseline conditions and for the three model scenarios for 1996 through 2012 simulation results (Table 1, Table 2, and Figure 3). The first year of simulation was removed to avoid model spin-up issues.

Table 1. Scenario results, concentrations, and mass at Yellow Medicine River mouth, 1996–2012

Parameter	Baseline	Scenario 1: Water and Sediment Control Basins	Scenario 2: Nutrient and Manure Management	Scenario 3: Cover Crops and Riparian Buffers
TSS median concentration (mg/L)	11.0	10.4	11.0	10.2
TSS mean concentration (mg/L)	41.3	39.7	41.3	40.4
TSS load (tons/yr)	8,904	7,055	8,985	8,535
Nitrate + nitrite median concentration (mg/L)	2.53	2.53	2.34	2.49
Nitrate + nitrite mean concentration (mg/L)	3.23	3.24	2.91	3.19
Total N median concentration (mg/L)	2.90	2.90	2.74	2.86
Total N mean concentration (mg/L)	4.75	4.73	4.43	4.69
Total N load (tons/yr)	927	874	735	908
Total P median concentration (mg/L)	0.08	0.08	0.08	0.08
Total P mean concentration (mg/L)	0.42	0.42	0.43	0.42
Total P load (tons/yr)	33.9	29.1	31.2	33.2

Table 2. Scenario results, percent changes relative to baseline

Parameter	Scenario 1: Water and Sediment Control Basins	Scenario 2: Nutrient and Manure Management	Scenario 3: Cover Crops and Riparian Buffers
TSS median concentration	-5.0%	-0.3%	-7.3%
TSS mean concentration	-4.1%	-0.1%	-2.2%
TSS load	-20.8%	0.9%	-4.1%
Nitrate + nitrite median concentration	-0.2%	-7.6%	-1.4%
Nitrate + nitrite mean concentration	0.1%	-10.0%	-1.3%
Total N median concentration	0.0%	-5.6%	-1.3%
Total N mean concentration	-0.3%	-6.7%	-1.3%
Total N load	-5.7%	-20.7%	-2.1%
Total P median concentration	1.1%	6.9%	-0.8%
Total P mean concentration	-1.3%	0.7%	-1.1%
Total P load	-14.2%	-8.0%	-2.1%

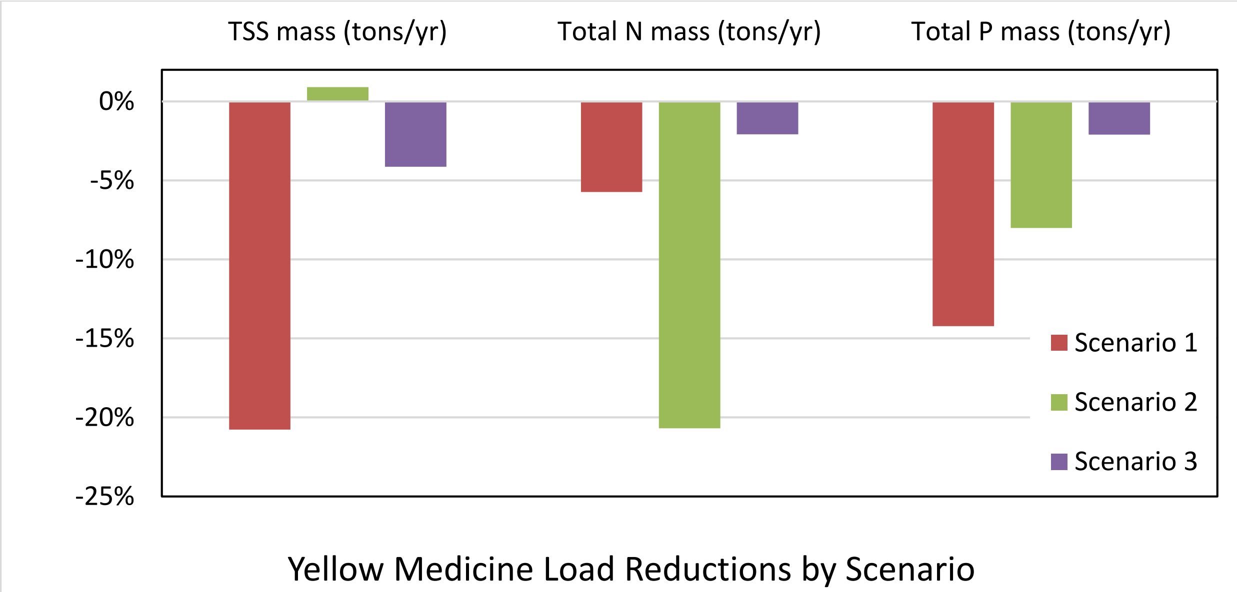

Figure 3. Changes in pollutant loading at Yellow Medicine River at Granite Falls by scenario

For Scenario 1, the water and sediment control basins that are simulated in this scenario primarily remove sediment through settling of particulates; the phosphorus that is adsorbed to the sediment is also removed, but the dissolved fractions of nutrients are not substantially changed. For phosphorus, 25 percent of the inorganic P load and 30 percent of the organic matter load is removed from the first two inches of runoff for the 50 percent of lands where treatment is applied. The basins also reduce peak flow velocities in the receiving streams and spread out the surface runoff peak, resulting in more deposition of phosphorus, for a net reduction in nonpoint source total phosphorus loads of about 14 percent and TSS load reductions of over 20 percent at the mouth of the Yellow Medicine River.

Scenario 2 (nutrient management) achieves large reductions in total N mass and somewhat lower reductions in total P mass loading (largely due to the significant P content of manure). Suspended solids loads are predicted to increase slightly due to the change in area of land receiving manure application.

Scenario 3 (buffers) shows only a small reduction in load. There are two reasons for this. First, the buffered area is only increased by 10 percent and effects of any existing buffers are already incorporated in the model calibration. Second, the net effect of the buffers is reduced at the watershed scale due to the assumptions regarding the fraction of flow that can be effectively treated in non-concentrated form.

3 References

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