Title: Improve Water Withdrawal Assessment Tool (WWAT) streamflow depletion allocations between Water Management Areas (WMAs)

Synopsis: The WWAT uses an algorithm (sometimes referred to as the "Half Max Rule)[1] to allocate the effects of a water withdrawal among the source WMA and neighboring WMAs. The way the algorithm is currently applied generally reduces the <u>total</u> amount of stream depletion attributable to each individual registered well. The algorithm is also normally used to apply the results from an SSR. The question is how to more realistically apportion the streamflow depletions in the screening tool, and for most SSRs.

Background:
Groundwater withdrawals develop a "cone of depression" and "capture" groundwater that may have otherwise flowed to several nearby streams. This process is affected by the amount of the withdrawal, the hydraulic properties of the aquifer, the connection between the streams and aquifer, the depth of the well, and the proximity of streams to the proposed well. A model[2] was developed for the WWAT to broadly account for these factors. In some cases, however, this method yielded nonsensical results, such as calculating depletions from streams that were far away when a major stream was nearby, or depleting a stream on the far side of a major stream. To minimize these nonsensical results and more realistically honor the hydrogeologic fact that drawdown cones stabilize when they reach stream boundaries that can satisfy the withdrawal demand, a refined method was implemented.

The current streamflow depletion calculation occurs in three steps. First, all neighboring WMAs are identified that touch the source WMA. Second, a streamflow depletion is calculated for each of these WMAs based on the distance from the proposed withdrawal to the *nearest stream segment* in each WMA. Third, the withdrawal depletions from these source and neighboring WMAs are evaluated and only those estimated depletions that are more than half the maximum depletion value from the entire group of WMAs under scrutiny are recorded in the WMA accounting database. Those calculated depletions that are less than 50% of the maximum value for the group are discarded. This method reduced the number of streams affected by a groundwater withdrawal to those closest to the withdrawal point and limited the evaluation to those streams having the greatest potential to significantly contribute to the withdrawal. However, as currently implemented, the depletion allocation routine in the WWAT ignores all the calculated depletions that are less than half the maximum, resulting in under prediction of the total

---

[1] Hamilton, D. A., and P. W. Seelbach. 2011. Michigan's Water Withdrawal Assessment Process and Internet Screening Tool. Michigan Department of Natural Resources, Fisheries Special Report 55, Lansing.

[2] Howard W. Reeves, David A. Hamilton, Paul W. Seelbach, and A. Jeremiah Asher, 2009, "Ground-Water-Withdrawal Component of the Michigan Water-Withdrawal Screening Tool", Scientific Investigations Report 2009-5003, U.S. Geological Survey.

depletion attributable to each proposed withdrawal. Also, the current method is not able to incorporate actual detailed spatial information about depletion amounts or extents. Recent advances in this field have provided better means to address this.

Findings:

The depletion calculations were examined for 30 actual registered wells in a variety of hydrogeologic settings across the state. The calculated stream depletions were reviewed for all of the neighboring WMAs. Using the current algorithm (1/2 max rule) in the WWAT, 74% of the total calculated depletions were included in the water accounting system (*i.e*., 26% of the total depletion amount was not accounted for). The range for individual wells was a high of 99% of the total depletion amount was accounted for to a low of only 49% of the total calculated depletion accounted for.

Zipper, et al. (2018), took the methodology developed for the WWAT and compared it with other techniques of identifying which neighboring streams should be depleted, and how much streamflow should be depleted.[3] They developed "Analytical Depletion Functions"[4] that consist of stream proximity criteria, depletion apportionment equations, and an analytical model to estimate streamflow depletion. These methods were applied to the same 30 example well locations in Michigan. The "adjacent" method (Figure 1), which uses Thiessen polygons to identify nearby stream segments that should be depleted, was selected as an improvement over the existing method. The "web squared" method (Figure 2) was selected to estimate the total depletion apportioned to each stream segment because it does a good job of incorporating the actual stream geometry relative to the drawdown cone. We continue to use the Hunt (1999)[5] solution for calculating the streamflow depletion. The results are summarized in Table 1. This approach has a strong theoretical foundation, it compares well with numerical models, it is being used by the British Columbia government in their water withdrawal program, and it was specifically developed as an improvement to our current methodology.

Recommendations:

1. Determine the feasibility of using the revised methodology in the screening tool. Develop techniques that will allow timely calculations in the online use of the tool. And determine the feasibility of conducting a field investigation to show improvement of the revised methodology versus the half max rule.

2. Determine the results of applying the revised methodology to the entire data base of registered large quantity withdrawals. Evaluate what, if any, impacts

---

[3] Zipper, S. C., Dallemagne, T., Gleeson,T., Boerman, T. C., & Hartmann, A. (2018). Groundwater pumping impacts on real stream networks: Testing the performance of simple management tools. Water Resources Research, 54, 5471–5486.

[4] Zipper, S. C., Gleeson, T., Kerr, B., Howard, J. K., Rohde, M. M., Carah, J., & Zimmerman, J. (2019). Rapid and accurate estimates of streamflow depletion caused by groundwater pumping using analytical depletion functions. Water Resources Research, 55, 5807–5829.

[5] Hunt, Bruce, 1999, Unsteady stream depletion from ground water pumping: Ground Water, v. 37, no. 1, p. 98–102.

there would be of water availability and potential ARIs. Identify possible measures to mitigate impacts on registered users while avoiding ARIs.

3. Prepare recommendations for the Water Use Advisory Council regarding the implementation of the revised methodology and any new or revised policies necessary for successful implementation.

Implementing Organization: Water Resources Division, EGLE.

Cost: The cost will be staff time using existing program funds.

Timeframe: One year.

Figure 1. Adjacent method to identify Stream segments for depletion.

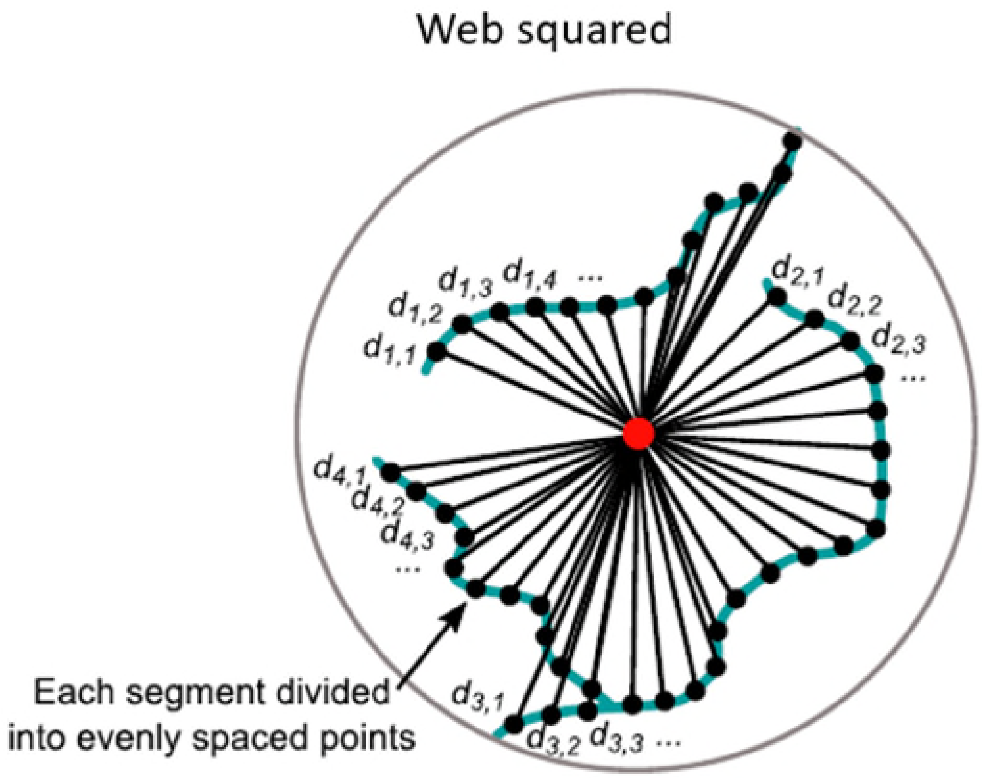

Figure 2. Web squared method to allocate portions of total streamflow depletion.

Table 1: Comparison original WWAT, WWAT with redistributing the total calculated depletion based on half max, and web squared depletion allocation.

Example	WWAT		WWAT w/total calc depl		web2	
	Depletion (gpm)	#WMAs Depleted	Depletion (gpm)	#WMAs Depleted	Depletion (gpm)	#WMAs Depleted
Barry1	267.5	1	501	6	552.5	3
Berrien1	5.4	1	7.3	9	9.4	3
Berrien2	40.9	2	63.2	5	67.6	3
Calhoun1	628.1	1	982.8	18	1127.6	1
Calhoun2	101.4	1	128.1	18	145	2
Cass1	56.9	2	71.9	5	73.3	3
Cass2	17.1	1	30	9	34	4
Gratiot1	97.6	1	116.7	6	93.4	2
Gratiot2	44	1	45.8	7	39.5	2
Hillsdale1	265.5	2	415.6	7	457.6	3
Iron1	33.4	2	42.5	6	48.1	3
Kalamazoo1	131.7	1	168.8	7	192.9	2
Kalamazoo2	70	2	85.2	4	79.8	2
Kalkaska1	15.1	1	26.4	7	30.3	4
Leelanau1	1.6	1	3	5	3.3	4
Livingston1	1.5	2	1.6	10	1.4	2
Montcalm1	202.6	1	203.4	7	204.3	3
Montcalm2	135.5	2	181.9	7	92	5
Newago1	29.3	1	59.4	9	58.5	3
Newago2	151.3	1	187.2	9	267.3	1
Oceana1	94	3	134.6	11	157.5	4
Oceana2	1.1	1	2.1	6	2.3	3
Ottawa1	26.7	1	29.1	11	26.3	4
St Joseph5	303.6	1	492.1	9	602.2	2
St. Joseph1	76.7	1	98.2	7	96.3	2
St. Joseph2	147.4	2	184.5	4	183.8	4
St. Joseph3	165	1	197.9	6	208.7	2
StJoseph4	175.8	1	228.9	9	220.1	3
Tuscola1	23.5	1	25.8	7	29.2	1
VanBuren1	2	1	2.8	5	3.2	2