Impacts of reservoir fluctuations on groundwater dynamics

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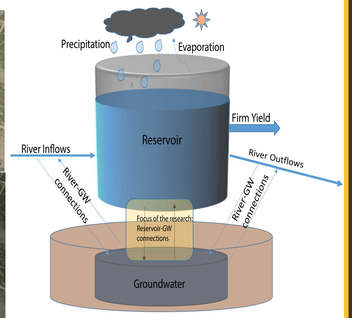
Motivation

1

Wetlands near the Lake Hattie Reservoir (Wyoming) . Images taken from Google Earth for Aug,2009 and Sep,2014. Approximate perennial wetland boundaries are outlined in red. Scales are same for both the images.



Water cycle of a reservoir with the purview of groundwater and its various connections.The effect of groundwater on firm yield has been found to significant and the groundwater contribution in water balance is substantial.[Archfield and Carlson,2006].

The research aims to find:

- What are the factors affecting the connections between reservoir and surrounding groundwater?
- How the groundwater movement is affected by the reservoir fluctuations?

Methodology

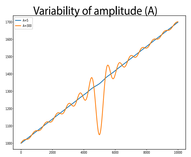
2

- The topography of an area plays a major role in the formation of groundwater flow systems [Toth, 1963].
- 2D models are created in MODFLOW-2005 to evaluate the effect of topography on reservoir levels on the groundwater flow and MODPATH is used to calculate the flow path lengths and transit times.
- The expression used in models for the synthetic topography is :

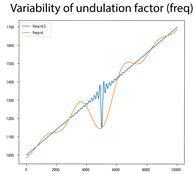
$$z = z_0 - A * \left(\frac{\sin\left(\pi * \frac{x - resloc}{180 * freq}\right)}{\pi * \frac{x - resloc}{180 * freq}} \right) + x * \tan(\alpha)$$

Where,

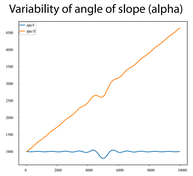
z= elevation of profile [meters]
A= factor similar to amplitude of the profile[meters]
freq= factor similar to inverse of frequency of the profile[meters]
resloc=location of reservoir[meters]
α= angle of the slope [degrees]
x=location[meters] ,z_0=minimum aquifer thickness(1000m).



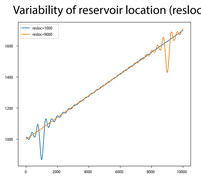
Variability of undulation factor (freq)



Variability of angle of slope (alpha)



Variability of reservoir location (resloc)



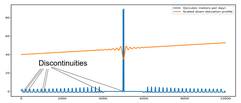
The water table ratio (WTR) determines whether the groundwater is controlled by recharge or topography. [Haitjema & Mitchell-Bruker 2005]. $WTR = \frac{RL^2}{mKHd}$ where R is recharge, K is conductivity, L is length between groundwater divide,H is aquifer thickness and d is terrain rise,m is factor dependant on shape (for our models m=8)

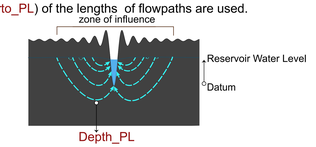
For our models, the ratio of recharge to hydraulic conductivity(R/K) ranges from 10^{-5} to 1 and WTR ranges from 10^{-5} to 10^{2}.

To quantify the effect of reservoir levels on the groundwater, few terms are introduced :

1.Zone of Influence(ZOI): The maximum horizontal extent of flowpaths which are connected with the reservoirs.
2.Number of dicontunities (NOD):The number of partitions happening between the recharge and discharge zones.
3.Groundwater discharge to Reservoir(GDR): GDR is the rate of volume of groundwater entering the reservoir.

Also the distribution of length of flowpaths and transit times will provide useful insights on the effect of reservoir on groundwater flows.Skewness(Skew_PL) and kurtosis (Kurto_PL) of the lengths of flowpaths are used.





Results

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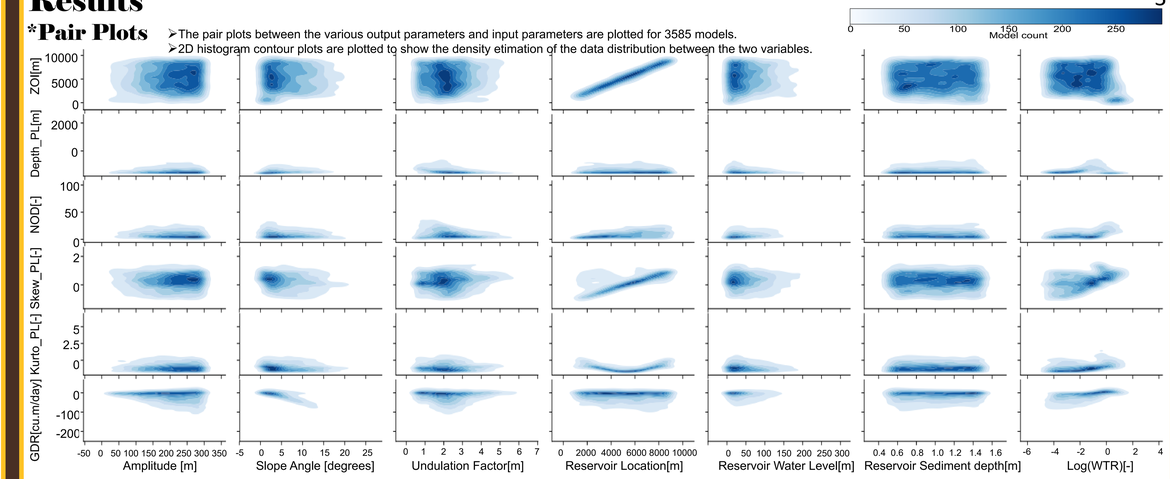
*Pair Plots

- The pair plots between the various output parameters and input parameters are plotted for 3585 models.
- 2D histogram contour plots are plotted to show the density etimation of the data distribution between the two variables.



*Behavior of Zone of Influence in Different Scenarios

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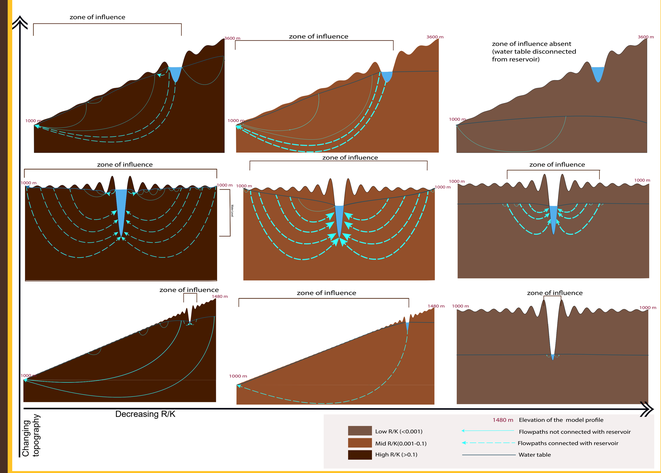

*GDR for various reservoir levels

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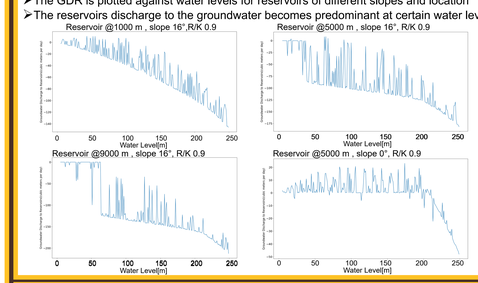
- The GDR is plotted against water levels for reservoirs of different slopes and location
- The reservoirs discharge to the groundwater becomes predominant at certain water levels.



*Groundwater discharge to wetlands

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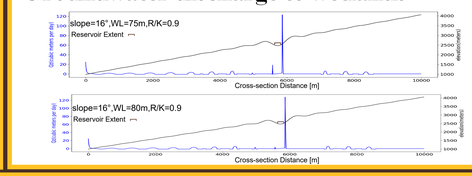

*Transit times of groundwater flow for different reservoir levels

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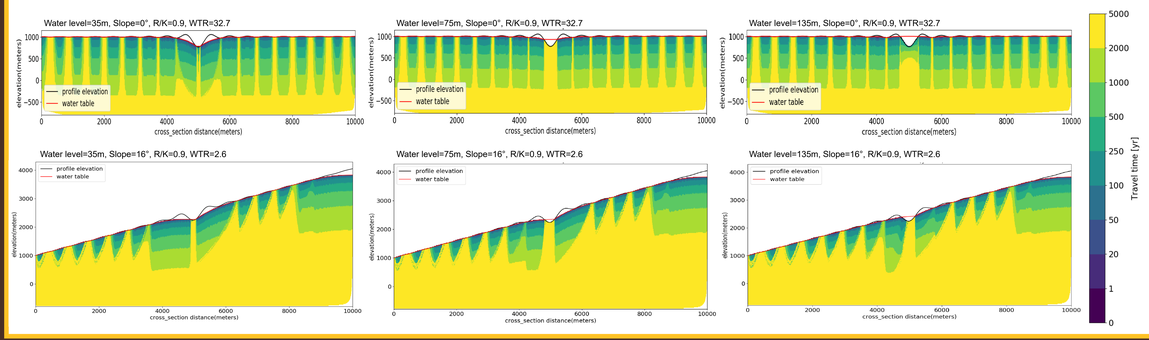

Significance

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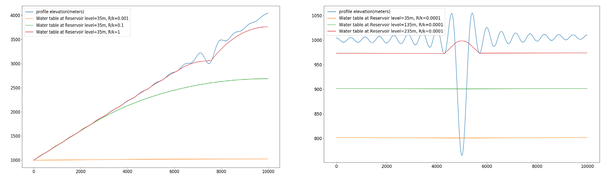
- The topographic factors, hydrologic factors and the reservoir levels play a significant role in the water table of the location and hence the flow paths and transit times.
- The groundwater discharge to reservoir (GDR) is dominantly affected by the regional slope and the R/K along with the dimensions of the reservoir and reservoir levels.
- The zone of influence (ZOI) depends on the undulation factor(freq) if the reservoir level is low and the R/K is high. If the regional slope(alpha) is high, the zone of influence also tends to increase with the height of reservoir, provided the water table is connected to the reservoir.
- The number of discontinuities (NOD) is directly proportional to the number of local undulations and is functional at high R/K values when the water table in near the surface.
- When the R/K is high, the change in reservoir levels results in changes the behavior of groundwater flow at least within the first topographic minima on either side of the reservoir and thus is significant for wetlands in those regions. The water to wetlands adjacent to reservoir is notably from regional groundwater flow and hence remains resilient to reservoir levels.

Discussion

9

- With low R/K values, the water table gets disconnected surface water bodies [Goderniaux et al, 2013].For reservoirs also is the same, given the reservoir nadir is not the minima of the topography.
- When the minima of topoghraphy coincides with reservoir nadir, the water table coincides with reservoir level. If reservoirs levels are high, the reservoir may contribute to the sustainance of wetlands or other surface water features.

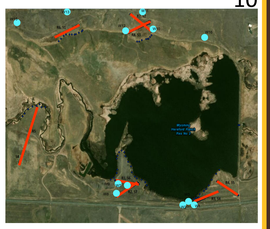


Ongoing Work

10

The validity of the models and results will be corroborated with a real world reservoir. Wyoming Hereford Ranch Reservoir 2(WHRR2) located in south east of Cheyenne, Wyoming is our field study site.

- ✓ 12 wells have been dug to measure the water table in the region
- ✓ Hydraulic Conductivity is measured from the core samples in the lab.
- ✓ Resistivity and seismic survey (8 lines of each) has been completed .
- ✓ Bathymetric survey of the reservoir has also been conducted.



References

11

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Acknowledgements

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