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EXTENDED ABSTRACT

A combined Time Series – Wavelet Model For Prediction of Ground Water Level (Case Study: Firuzabad Plain)

S. M. Salehi[1], F. Radmanesh[2*], H. Zarei[3], B. Mansouri[4] and A. Solgi[5]

1- MSc of Water resource Engineering Department of Shahid Chamran University, Ahvaz, Iran.
2*- Corresponding Author, Associate Professor, Water Engineering Department, Shahid Chamran University, Ahvaz, Iran.*(radmanesh@scu.ac.ir).*
3- Associate Professor, Water Engineering Department, Shahid Chamran University, Ahvaz, Iran.
4-Assistant Professor, Faculty of Mathematics and Computer Sciences, Shahid Chamran University of Ahvaz, Iran.
5-PhD Candidate, Faculty of Water Sciences, Shahid Chamran University of Ahvaz, Iran.

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Introduction:

Recently, the phenomenon of climate change, drought, the exploitation of the ground water has caused a sharp decline in groundwater levels, which has also led to groundwater related subsidence and desertification. Therefore, reliable prediction of groundwater level for managing these resources is of prime importance. Nowadays wavelet transforms through signal decomposition to time and frequency has created an exceptional method for signal processing, with the help of the transformation of the wavelet that has the ability to split the time series into a multi-dimensional substrate with different scales.

One of the useful characteristics of wavelet transforms is the filtering algorithm, which divids the data into two groups of approximation and details by passing them through the wavelet filter. In this study, monthly groundwater surface, rainfall, and temperature data were used. Using the program code written in MATLAB software, it is necessary to analyze the time series data of all three parameters of temperature, precipitation, and water level. The values of the parameters were selected as inputs and placed in the wavelet function. For analyzing all the parameters, according to various mother-wavelet experiments, and considering the above mentioned point, five mother-wavelets (Haar, Coif, Symlet, Db, Db4) were selected. For this purpose, the program was first implemented for each of the following wavelets with 4 different decomposition levels. After several software runs under specific conditions and scenarios and then comparing them with each other, results were obtained.

Results and Discussion

In order to study and investigate the status of the groundwater level in this area, the hydrograph of all wells was drawn. Then, based on the rate of decline and fluctuation, all wells were classified into five groups, which are presented in Table (1).

Table 1- Classification of wells based on the level's decline and fluctuations

Weak fluctuations	Intense fluctuations	fluctuations intensity / Decline intensity
-	A	Intense fluctuations(40 to 60 m)
C	B	Intense Decline(20 to 40 m)
E	D	Moderate Decline (0 to 20 m)

Subsequently, from each group, according to its frequency, a series of wells were selected, then an accurate investigation of the area was performed in terms of hydrological characteristics and conditions, so that some of the characteristics of the groups and the similarities of the wells were obtained and found in each group.

Groundwater level modeling results using ARIMA and Wavelet time series models

The structure and results obtained from the modeling of ARIMA time series models for all wells at the training and testing stages are presented in Table (2).

In the next step, using the functions of the Daubechies wavelets (d and d4), the Coiflet wavelet function (c), the Haar wavelet function (h), the Symlet wavelet function (s) through the implementation of the above functions in the program code written via the MATLAB software, data analysis was carried out. Then, using the decomposed data, Arima Time series was modeled (in the training stage).

Therefore, for each well, using all the decomposition states, the simulation (at the testing stage) was considered; finally, by computing and comparing the above criteria, the ability and acceptability of the models were investigated. Then, using the criteria, according to the lowest error rate, the best method for each well was selected, which is listed in Table (3).

Comparing tables (2) and (3), it can be concluded that, unlike the serial model, when the simulation of some wells failed, the wavelet time series model has been simulated appropriately.

In order to predict the groundwater level, the db4 function of the Daubechies family is the most appropriate wavelet function, and the second decomposition level is the most appropriate decomposition level.

Table 2- Structure and results obtained from time series modeling of observation wells

Arima Time Series Model									
Test Stage				Training stage				Well name	Group
AIC	RMSE	R^2	ARIMA Model	AIC	RMSE	R^2	ARIMA Model		
39.70	0.017	0.90	(0,1,9)	444.85	0.024	0.97	(0,1,5)	A1	A
40.36	0.021	0.70	(0,1,12)	444.19	0.020	0.98	(0,1,12)	B1	
43.13	0.052	0.70	(3,1,12)	445.31	0.028	0.96	(0,1,9)	B2	B
41.01	0.026	0.17	(0,1,7)	444.02	0.018	0.98	(3,1,3)	B3	
36.54	0.006	0.84	(0,1,12)	442.03	0.009	0.99	(0,1,12)	C1	C
42.03	0.036	0.41	(0,1,12)	444.89	0.025	0.96	(1,1,12)	D1	
42.57	0.043	0.19	(0,1,12)	445.15	0.027	0.96	(0,1,12)	D2	D
38.37	0.011	0.15	(0,1,12)	444.00	0.018	0.99	(0,1,12)	D3	
39.60	0.016	0.13	(0,1,18)	444.35	0.021	0.98	(0,1,18)	E1	E
37.50	0.008	0.89	(2,1,2)	443.02	0.013	0.99	(2,1,2)	E2	

Table 3- Structure and results obtained from wavelet time series modeling of observation wells

Wavelet Arima Time Series Model											
Test Stage					Training stage					Well Name	Group
AIC	RMSE	R^2	ARIMA	Superior Wavelet	AIC	RMSE	R^2	ARIMA	Superior Wavelet		
9.00	0.008	0.97	(0–1–12)	Σ2	414.64	0.009	0.99	(0–1–12)	S2	A1	A
6.89	0.007	0.96	(0–1–2)	δ42	411.08	0.007	0.99	(0–1–2)	db42	B1	
14.81	0.015	0.97	(0–1–5)	δ42	414.89	0.010	0.99	(0–1–12)	db42	B2	B
–4.14	0.009	0.85	(0–1–12)	X3	404.40	0.009	0.99	(0–1–12)	C3	B3	
–41.67	0.005	0.99	(0–1–16)	δ44	372.01	0.006	0.99	(0–1–16)	db44	C1	C
–6.19	0.02	0.80	(0–1–0)	η4	394.35	0.02	0.98	(0–1–0)	h4	D1	
13.37	0.014	0.88	(0–1–12)	δ42	414.81	0.010	0.99	(0–1–12)	db42	D2	D
19.36	0.004	0.82	(0–1–12)	δ41	427.21	0.007	0.99	(0–1–12)	db41	D3	
5.46	0.006	0.80	(2–1–1)	δ42	412.95	0.008	0.99	(2–1–1)	db42	E1	E
–32.07	0.004	0.97	(1–1–1)	δ44	378.09	0.006	0.99	(0–1–4)	db44	E2	

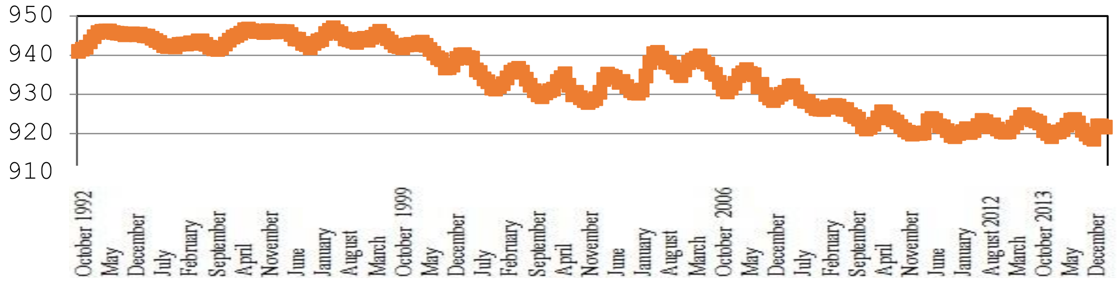

Figure 1 - Firozabad plain Groundwater Level Hydrograph for the statistical period and the next three months is predicted.

Conclusion

Due to the sharp decrease in groundwater resources, an accurate prediction of groundwater level is necessary. Therefore, in this study, the prediction of the surface water level of Firozabad plain was carried out using a time-wavelength-series combination model. At first, the hydrograph of all wells was drawn, and as a result a decline of groundwater level for all of the wells was obvious. Then, based on the severity of the declining and groundwater level fluctuations, they were divided into five groups, and to avoid repetition of calculations, each due to the location of wells in the area, a group of wells was selected. Each group was decomposed using 5 wavelet and 4-level functions and was considered as input for the time series model. The modeling at the training stage was performed using 90% of the data and simulation at the test stage using 10% of the data. The results were compared with the results of the Arima time series model and the observation wells were divided into three groups. The results showed the superiority and precision of the wavelet-time series combination model. Among the different modes and functions of Db4, the Daubechies family and the second decomposition level have the best function and level of analysis in groundwater studies. Then, predicting the groundwater level of all of the wells during the next three months was performed. At the end, the hydrograph of the plain was plotted during the statistical period and the predicted values of the next three months, and it indicates a sharp decrease in groundwater level in the plain. The plain hydrograph is shown in Fig. (1).