UNIVERSITI PUTRA MALAYSIA

GROUNDWATER RESOURCE ASSESSMENT IN ASTANEH-KOUCHESFAHAN PLAIN, IRAN

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BY
MASOUD SAATSAZ

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To my wife and the best friend, Masiha
Without her support, I could not have been the man I am today…

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

GROUNDWATER RESOURCE ASSESSMENT IN ASTANEH-KOUCHESFAHAN PLAIN, IRAN

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Chairman: Associate Professor Wan Nor Azmin B Sulaiman, PhD

Faculty: Environmental Studies

Astaneh-Kouchesfahan Plain is one of the focus points in terms of regional development in north of Iran. The socio-economic resources of the plain are enormous and play a particularly important role in supporting the rural population of the area. Partial use of groundwater potential, increase in irrigation demand and groundwater contamination have caused the cultivable lands not to be fully exploited and because of secondary salinity and erosion, surface soils gradually are being converted to idle lands. This problem has brought some difficulties for economical development of the area that has led to decrease of family income, unemployment and finally immigration of rural people. Most of these difficulties are due to mismanagement of water resources caused by lack of reliable data. Hence, for overcoming these difficulties, a detailed regional quantitative and qualitative assessment of groundwater resources has been proposed and the results have been analyzed based on standard methods. The base investigations were carried out to develop hydrogeological and hydrochemical frameworks of the

groundwater system. Based on available data, average annual water balance has been evaluated for the whole region. Groundwater balance study indicates that despite of water deficiency for domestic and agricultural usages, discharge from groundwater is less than recharge to the region. The results show that total recharge into the system is of the order of 342.89 million m^3 (MCM), whereas the total discharge is of the order of 332.89 MCM, leaving a surplus balance of +9.99 MCM. From the hydrochemical point of view, the groundwater sources in the Astaneh-Kouchesfahan Plain have been evaluated for their chemical composition and suitability for drinking and irrigation uses. Comparison of geochemical results with World Health Organization and United States Environmental Protection Agency standards show that most groundwater samples except few are permissible for drinking purposes and based on the Wilcox diagram, nearly all of the groundwater samples are fit for irrigation use in almost all soil types. The groundwater in the region was classified as hard, fresh to brackish, medium to high saline and slightly alkaline in nature. The Piper plot illustrates that most of the groundwater samples analyzed during the pre-monsoon and post-monsoon fall in the field of Ca-HCO_3. In order to achieve a better understanding of the nature of the factors influencing ground water composition, the correlation studies and R-mode factor analysis were carried out on the various groundwater parameters and the factor scores were transferred to areal maps. The results of factor analysis show that factor 1 of the pre-monsoon and factor 2 of the post-monsoon have high loading in the ions Na^+ and Cl^-, reflecting that these ions are mainly derived from dissolution of secondary

salts precipitated in the pore spaces and anthropogenic sources such as agricultural activities and influx of municipal effluents.

After hydrochemical investigations, the groundwater vulnerability to pollution was evaluated using GIS DRASTIC model and the obtained results showed the areas with low, moderate, high and very high groundwater vulnerability potential cover around 12, 52, 28 and 8% of study area, respectively. The high and very high vulnerable zones mainly located in middle parts of the plain and hence, groundwater resources beneath such areas need to be monitored continuously so that protective measures can be established. In this study, a 2-Dimentional groundwater flow model was also developed and calibrated to simulate and predict hydraulic heads under steady-state and transient conditions; to optimize hydrogeological coefficients values of aquifer; as a prerequisite, to develop a contamination-transport model and finally, to validate GIS DRASTIC model using model scenario testing. The results of the transient calibration indicate that the horizontal hydraulic conductivity values ranges from 1 to 23 m/day; and the specific yield of the aquifer ranges between 0.03 and 0.25. After model verification and assurance the reliability of the model results, the model prediction has been done for the period from October 2009 to October 2012 and it has been predicted that according to present recharge and discharge conditions, the average weighted groundwater levels rise about 0.34 m. At the same period, the predictive results of solute transport model show that according to present flux conditions, groundwater salinities increased by approximately 2% over the period and the average weighted chloride concentration increases from

136.36 to 138.89 mg/L. However, if current conditions prevail, it is expected that the groundwater consumers of the aquifer will be facing a worse situation than the present condition.

Key Words**:** Aquifer Management, Aquifer Vulnerability, Astaneh-Kouchesfahan Plain**,** DRASTIC, GIS, Groundwater Balance, Groundwater Pollution, Groundwater Simulation, Hydrochemistry, Hydrogeology, Iran, MT3D Model, , Numerical Modeling, PMWIN Model, Recharge, Water Budget, Water Quality.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN SUMBER AIR TANAH DI DATARAN ASTANEH-KOUCHESFAHAN, IRAN

Oleh

MASOUD SAATSAZ

November 2011

Pengerusi: Profesor Madya Wan Nor Azmin B Sulaiman, PhD

Fakulti: Pengajian Alam Sekitar

Dataran Astaneh-Kouchesfahan adalah salah satu titik fokus dalam hal pembangunan daerah di utara Iran. Sumber sosio-ekonomi dataran sangat besar dan memainkan peranan yang sangat penting dalam menyokong penduduk luar bandar di daerah tersebut. Sebahagian penggunaan potensi simpanan air tanah, peningkatan permintaan pengairan dan pencemaran air tanah telah menyebabkan tanah pertanian tidak sepenuhnya dieksploitasi dan kerana kemasinan dan hakisan sekunder, permukaan tanah secara berperingkat bertukar kepada tanah terbiar. Masalah ini telah membawa beberapa kesulitan untuk pembangunan ekonomi kawasan itu yang telah menyebabkan penurunan pendapatan keluarga, pengangguran dan akhirnya perpindahan masyarakat luar bandar. Sebahagian besar dari kesulitan-kesulitan ini disebabkan oleh salah urus sumber air yang disebabkan oleh kurangnya data yang boleh dipercayai. Oleh kerana itu, untuk mengatasi kesulitan-kesulitan ini, penilaian kuantitatif dan kualitatif terperinci kawasan sumber air tanah telah dicadangkan dan hasil telah dianalisis berdasarkan

kaedah piawai. Penyelidikan asas dilakukan untuk membangunkan rangka kerja hidrogeologi dan hidrokimia bagi sistem air tanah. Berdasarkan data yang ada, purata keseimbangan air tahunan telah dinilai untuk seluruh kawasan. Kajian keseimbangan air tanah menunjukkan bahawa walaupun kekurangan air untuk kegunaan domestik dan pertanian, luahan air tanah kurang daripada imbuhan ke kawasan tersebut. Keputusannya menunjukkan bahawa jumlah imbuhan kepada sistem adalah 342.890 juta m^3 (MCM), sedangkan jumlah luahan ialah 332.89 MCM, meninggalkan baki lebihan +9.99 MCM. Dari sudut hidrokimia, sumber air tanah di Dataran Astaneh-Kouchesfahan telah dinilai untuk komposisi kimia dan kesesuaian untuk kegunaan air minum dan pengairan. Perbandingan keputusan geokimia dengan piawaian Pertubuhan Kesihatan Dunia dan Environmental Protection Agency Amerika Syarikat menunjukkan bahawa kebanyakan sampel air tanah berada pada tahap yang dibenarkan untuk keperluan minum dan berdasarkan rajah Wilcox, hampir semua sampel air tanah sesuai untuk penggunaan pengairan di hampir semua jenis tanah. Air tanah di kawasan-kawasan tersebut diklasifikasikan sebagai keras, segar ke payau, sederhana ke tinggi masin dan sedikit semulajadi alkali. Plot rajah Piper menggambarkan bahawa sebahagian besar sampel air tanah dianalisis semasa musim sebelum monsun dan selepas monsun tergolong dalam Ca-HCO_3. Untuk mencapai pemahaman yang lebih baik tentang faktor-faktor semulajadi yang mempengaruhi komposisi air tanah, kajian korelasi dan analisis faktor R-mode dilakukan pada berbagai parameter air tanah dan skor faktor tersebut dialihkan ke peta luas. Keputusan analisis faktor menunjukkan faktor 1 dari sebelum monsun dan faktor 2 dari selepas monsun mempunyai

beban ion Na^+ dan Cl^- yang tinggi, mencerminkan bahawa ion-ion berasal dari pelarutan garam sekunder terenap dalam ruang pori dan sumber antropogen seperti kegiatan pertanian dan influks sampah kota.

Selepas siasatan hidrokimia, air tanah "mudah terdedah kepada pencemaran" dinilai menggunakan model GIS DRASTIC dan keputusan yang diperolehi menunjukkan kawasan dengan potensi air tanah mudah terdedah tahap rendah, sederhana, tinggi dan sangat tinggi masing-masing merangkumi sekitar 12, 52, 28 dan 8% dari kawasan kajian. Zon mudah terdedah tinggi dan sangat tinggi terletak di bahagian tengah dataran dan dengan itu, sumber air tanah di bawah kawasan-kawasan tersebut perlu dipantau secara berterusan supaya tindakan perlindungan dapat dibuat. Dalam kajian ini, model aliran air tanah 2-Dimensi juga dibangunkan dan ditentukur untuk mensimulasikan dan meramalkan turus hidraulik di bawah keadaan mantap dan fana, untuk mengoptimumkan nilai pekali hidrogeologi akuifer, sebagai prasyarat, untuk membangunkan model pencemaran-pengangkutan dan akhirnya, untuk mengesahkan model GIS DRASTIC menggunakan ujian senario model. Keputusan tentukur fana menunjukkan bahawa nilai konduktiviti hidraulik mendatar berjulat daripada 1 ke 23 m/hari, dan hasil tentu dari akuifer berjulat antara 0.03 dan 0.25. Selepas pengesahan model dan jaminan kebolehpercayaan keputusan model, model ramalan telah dilakukan untuk tempoh dari Oktober 2009 hingga Oktober 2012 dan telah menganggarkan bahawa mengikut keadaan imbuhan dan

luahan pada masa ini, aras purata air tanah meningkat sekitar 0.34 m. Pada tempoh yang sama, hasil ramalan dari model pengangkutan bahan larut menunjukkan bahawa mengikut keadaan fluks sekarang, kemasinan air tanah meningkat sekitar 2% selama tempoh itu dan purata kepekatan klorida meningkat daripada 136.36 kepada 138.89 mg/L. Namun, jika keadaan semasa ini berlaku, dijangka pengguna air tanah akuifer tersebut akan menghadapi situasi yang lebih buruk daripada keadaan sekarang ini.

Kata kunci: Pengurusan Akuifer, Kerentanan Akuifer, Dataran Astaneh-Kouchesfahan, DRASTIC, GIS, Keseimbangan Air Tanah, Pencemaran Air Tanah, Simulasi Air Tanah, Hidrokimia, Hidrogeologi, Iran, Model MT3D, Permodelan Berangka, Model PMWIN, Imbuhan, Anggaran Air, Kualiti Air.

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I certify that an Examination Committee has met on 23 November 2011 to conduct the final examination of Masoud Saatsaz on his thesis entitled "Groundwater Resource Assessment in Astaneh-Kouchesfahan Plain, Iran" in accordance with Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998.The committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

MASOUD SAATSAZ

Date: 23 November 2011

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