Augmentation of groundwater by managed aquifer recharge around a non perennial river

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ABSTRACT: (9 pt)
Check dams for intentional storage of surface runoff is often preferred as a method of managed aquifer recharge in non-perennial rivers. The objective of this study is to assess the improvement in groundwater storage by a check dam constructed across Arani River located north of Chennai, India. Groundwater level was measured around the check dam before and after its construction. After the construction of the check dam, water level in the dam was also measured. The groundwater table was generally at a depth of 12 m below ground level before the construction of check dam. After the construction of check dam, the groundwater level has increased by about 2 m. The temporal variation in groundwater level was compared with the water level fluctuation in the check dam. The groundwater level fluctuation in wells that are located closer to the dam is similar to the water level fluctuation in the check dam indicating that the water stored in the dam recharges them. Based on the water level measurements it is estimated that this check dam harvest about 1.8 Mm^3 of surface water every year and about 66% of this water is recharged. An area of about 3 km^2 is benefited by raise in groundwater level around the check dam. The study carried out over the period of two years after the construction of this check dam indicates no reduction in recharge due to expected physical or biological clogging. Hence, managed aquifer recharge by check dam across this river is augmenting groundwater storage in this area.

1. INTRODUCTION

Dependence on groundwater has increased in areas where surface water resources are limited and rainfall is seasonal. Groundwater is extracted for various purposes in such areas, which causes the rapid decline in groundwater table. Various Managed aquifer recharge (MAR) methods may be adopted in order to increase groundwater potential in such regions. Gale et al., (2006) describes MAR as intentional storage and treatment of water in aquifers. Selection of particular MAR method depends very much on the hydrogeology, quantity and quality of the water to be recharged. Methods of MAR include aquifer storage and recovery (ASR), aquifer storage, transfer and recovery (ASTR), infiltration ponds, infiltration galleries, soil aquifer treatment, percolation tanks and check dams (Dillon et al., 2009). MAR will be helpful in enhancing water supplies, improving groundwater quality, preventing saltwater intrusion into coastal aquifers, reducing evaporation of stored water, mitigating floods and improving the urban landscape, which increases urban land value (Gale et al., 2006). Check dam is one of the methods of MAR constructed across the non perennial rivers. It is the best and suitable method in regions with unconfined aquifers. Hydrological measurements will be helpful to evaluate the efficacy of check dam to understand the improvement on water level. Many research works have been carried to assess its impact by using hydrological measurements such as water level measurements, water quality parameters and isotopic analysis. Groundwater water level data is a best indicator to know the improvement on groundwater recharge. Improvement on groundwater recharge due to the construction of check dam using water level measurement is carried out by Alderwish, 2010; Al-Muttair et al., 1994; Ashraf et al., 2007; Al-Turbak, 1991; Gale et al., 2006; Mudrakartha, 2003; Muralidharan, 2007. Improvement on groundwater quality around the check dam vicinity is assessed by water quality parameters and this is been assessed by Bhagavan &Raghu, 2005; Gale et al., 2006; Bijukumar and Abraham, 2009; Mudrakartha, 2003; Palanisami et al., 2006; Samarah et al., 2009. The present study was carried out with the objective of assessing the impact of a check dam constructed across Arani River as a method of MAR in near Chennai in augmenting groundwater.

2. STUDY AREA

Chennai basin is spread across Thiruvallur, Kancheepuram and Vellore districts of Tamil Nadu. Araniar, Koratalaiyar, Cooum and Adyar are the four important rivers draining the basin. Annual average rainfall of this area is about 1200mm and the monthly variation in rainfall is shown in Fig.1. Chennai city's water requirement is met from the reservoirs and lakes namely Poondi, Sholavaram, Redhill, Chembarambakkam and Veeranam. It has four major water treatment plants together they are capable of treating around 10,280 million litres per day. The city also gets its groundwater supply from well fields in the Araniyar-Koratlaiyar (A-K) basin.

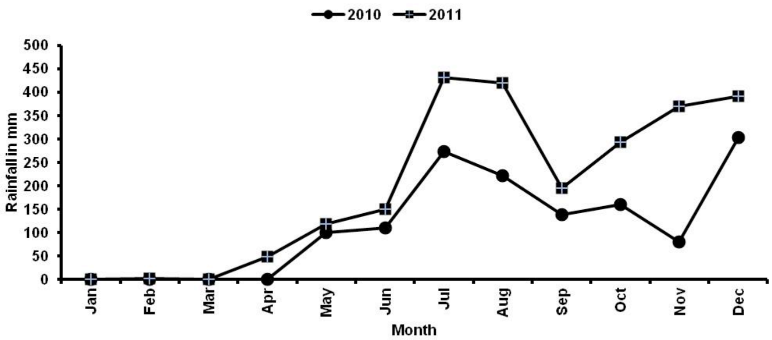

Figure 1. Rainfall pattern in Chennai

About 180 million litres per day of groundwater is extracted from these basins to supplement the drinking water needs of the city population. Though contribution of groundwater is very less, it is of greater importance during summer period when the surface reservoirs become empty. Fast rate of depletion of groundwater level in Arani-Korataliar basin is due to the continuous pumping of groundwater for city's water supply and extraction of groundwater by farmers for irrigation purpose. Hence, in order to maintain the yield of the aquifers and to supply assured water supply to the city certain long-term water management measures such as construction of check dam across Arani-Korataliyar Rivers have been proposed by the Government to augment the groundwater resources.

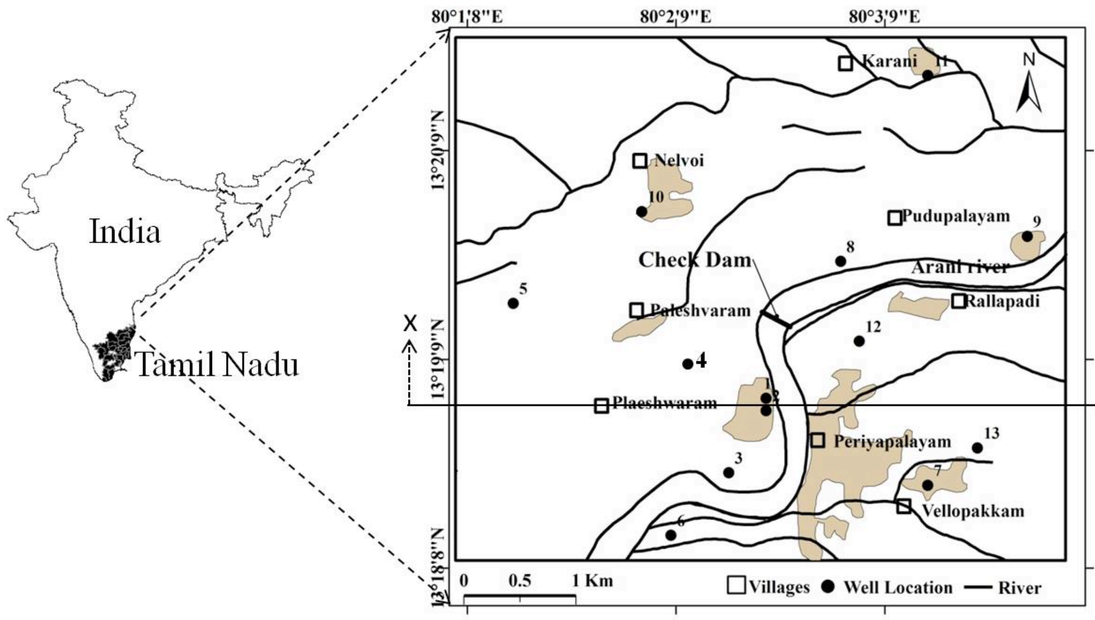

Figure 2. Location of check dam and monitoring wells in the study area

One such check dam constructed in the year 2010 across Arani river, near Paleshwaram village was taken up for the present study. This check dam is of 260m length with the crest height of 3.5m from the river bed and has storage capacity of 0.8 Million cubic meter of water. The location of check dam and monitoring wells are shown in Fig .2. This area comprises of alluvial deposits up to 50m from the ground surface, which are underlined by low permeability rocks of pre-quaternary age. The alluvium consists of sand, clays and lenses of clay (Elango, 1986). The transmissivity of the sand and gravel layer is 2000 m2/day to 6000 m2/day and for the clay layer it is less than 500m2/day (Charalambous and Garratt, 2009). Groundwater flow is from the west to east direction and follows the topography of the surface. Intensive agriculture is practiced throughout the study area and groundwater is the major source for irrigation.

3. METHODOLOGY

Field survey was carried out during July 2010 and 19 monitoring wells located around the check dam was considered for periodical monitoring. Groundwater level in the wells were measured once in three months from July 2010 (before the construction of check dam) to December 2010 and once in a month from January 2011 to May 2012 using the water level meter (Solinist 101). Water level in the check dam was measured through the manual staff gauge installed in the check dam. Elevations of monitoring wells and topographic variations of the river bed were measured using the Differential global positioning system (Leica GS09). Surface area and volume of water stored in the check dam under different water level was calculated using ArcGIS 9.2 software.

4. RESULTS AND DISCUSSIONS

This study was carried out based on the observations of surface water level from the check dam and groundwater level from the monitoring wells located surrounding the check dam. The rainfall pattern of this study area is shown in Fig.1 for the period of 2010 and 2011, which indicate a maximum rainfall in December 2010 as well as during November 2011.

4.1 Groundwater table before and after construction of check dam

Groundwater level measurement is a good indicator to identify the efficacy of MAR structures before and after construction. Groundwater fluctuation for a particular year depends upon the quantity of groundwater recharge, which in turn depends on the amount of rainfall. Comparison between groundwater level measured before and after construction of the check dam will help in identifying the impact of this structure on groundwater table improvement.

4.1.1 Groundwater table before construction of check dam

Groundwater table was generally at a depth of 3 m to 12 m below ground level before the construction of check dam. Before the construction of the check dam in this area the groundwater level variation was mainly due to the rainfall recharge. In order to identify the impact of check dam on groundwater level, a comparison is made between of groundwater table before and after construction of the check dam. The approximate groundwater table before construction of check dam along x-x' axis (Fig.1.) during July 2010 is shown Fig.3. Minimum and maximum water levels observed before construction of check dam varies from 13.8 m to 15 m (MSL). Almost all the open shallow wells were dry in July 2010 in spite of the rainfall of 483 mm from May to July 2010.

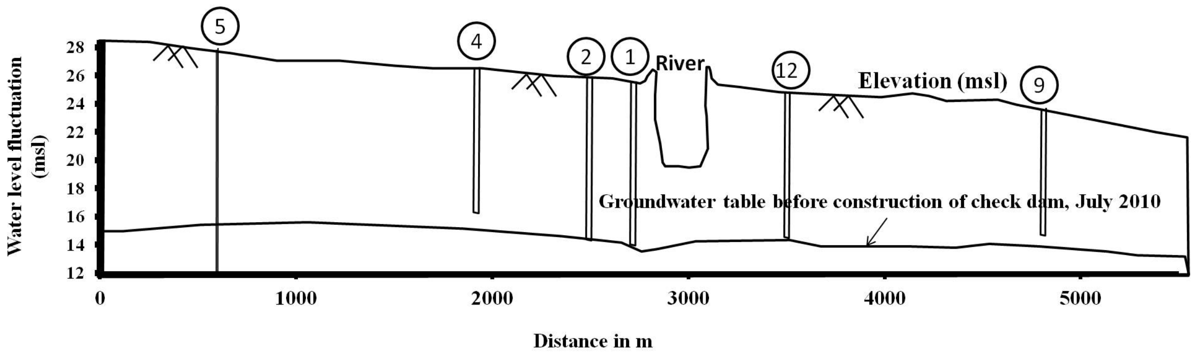

Figure 3. Groundwater table before construction of check dam

4.1.2 Groundwater table after construction of check dam

The groundwater table after construction of check dam along x-x' axis (Fig.1.) during July 2011 is shown Fig.4. The groundwater level measured would have been due to the recharge from rainfall of 267 mm from May to July 2011 and recharge from check dam. The rainfall from May to July 2010 (before construction of check dam) was 483mm, about 50% higher than the rainfall from May to July 2011. Even though the amount of rainfall in May to July 2011 is lesser than the previous year, there is considerable increase in groundwater table in 2011 than in 2010 as seen in Fig. 4. Hence, the comparatively higher groundwater level in 2011 is due to recharge by the check dam. The maximum water level of 17 m (msl) was measured near the check dam and the wells located near the check dam were not dry in July 2011 after construction of the check dam. Even though groundwater pumping for various purposes would have also controlled the groundwater level, the pumping pattern would have been more or less the same during both 2010 and 2011.

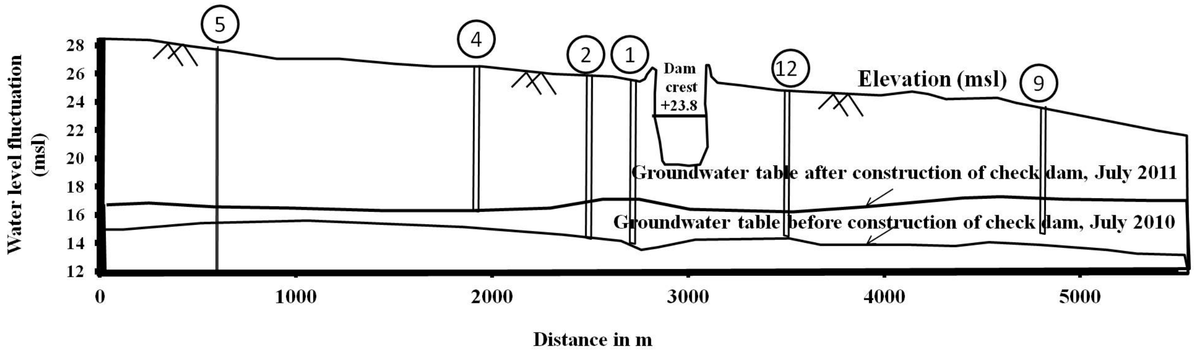

Figure 4. Water table before and after construction of check dam

4.2 Temporal variation of surface and groundwater levels

Efficiency of the check dam in augmenting the groundwater recharge was assessed by comparing the temporal variation between water level in the check dam and groundwater level in the wells. Based on the similarity between the water level fluctuation in the check dam and groundwater level, the wells could be classified into two groups. As examples plot of four wells (Well nos 1,11,12,13) are shown in Fig.5. In the first group of wells (Well nos 11,13) groundwater level raise twice a year coinciding with the north east and southwest monsoon. These indicate that rainfall is the major source of recharge at these locations.

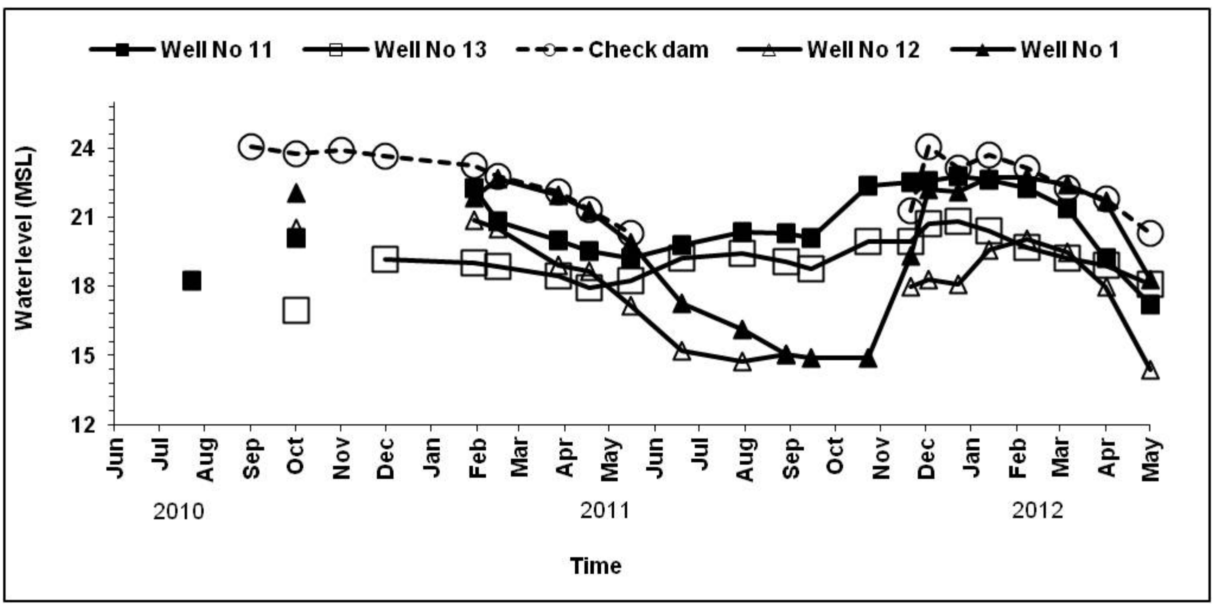

Figure 5. Temporal variation between water level in the check dam and groundwater

Whereas in the other group of wells (Well nos 1,12) fluctuation in groundwater levels are very similar to the water level fluctuation in the check dam. This similarity indicates that surface water stored by the check dam is the major source of recharge at these locations. An area of about 3 km^2 is benefitted by raise in groundwater level around the check dam.

4.3 Recharge from check dam

Water level fluctuation in the check dam is shown Fig.6. During monsoon season, check dam reaches its maximum crest level of +23.8 m msl and even it was overflowing for more than two weeks during the study period. Based on the water level measurement from the check dam it was estimated that this check dam harvest about 1.8 Mm^3 of surface water every year.

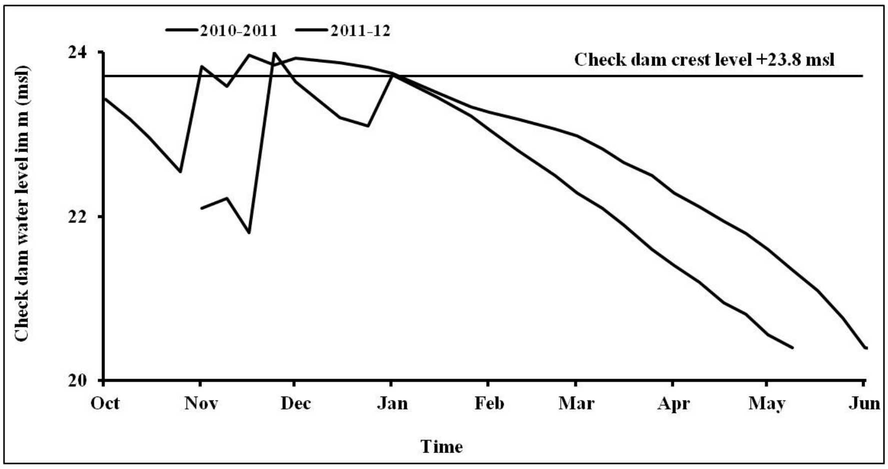

Figure 6. Water fluctuation in the check dam for the year 2010-2011 and 2011-2012

3D analytical capability of ArcGIS 9.2 was used to estimate the surface area and volume of water stored in the check dam corresponding to various water levels in the check dam. Volume of water infiltrated from the structure was estimated using the water balance method as given Eq.1.

$$\text{Infiltration (m}^3\text{) = Change in storage (m}^3\text{) – Potential Evaporation (m}^3\text{)} \quad (1)$$

Estimation of recharge from the check dam was calculated based on the bimonthly water level measurement from the month of January after which there is no overflow and inflow to the structure is observed. Data of potential evaporation was obtained from the Indian Meteorological Department, Chennai. Table.1 gives the results obtained by the water balance method and about 66% of the water stored by the check dam was recharged into the aquifer.

Table 1. Recharge from the check dam using water balance method

Date	Check dam water level (msl)	Volume of water stored (m^3)	Evaporation (m^3)	Change in storage (m^3)	Infiltration (m3)
Jan-12	23.23	577297			
Feb-12	22.436	281243	87727	296054	208327
Mar-12	21.568	62702	76478	218540	142062
Apr-12	20.728	10879	24158	51823	27666
May-12	20.308	7	2819	10872	8054

Analysis of check dam water level variations with respect to two years (2010-2011 and 2011-2012) indicate that there was no reduction in the rate of recharge as the variation in the water level for the year 2010 – 2011 and 2011 – 2012 were more or less the same. This indicate that during the period of two years after the construction of check dam there was no reduction in recharge due to expected physical or biological clogging.

5. CONCLUSION

Groundwater augmentation by MAR in a non-perennial river was assessed by measuring the surface water levels from check dam and groundwater level from wells located surrounding the structure. After construction of the check dam the groundwater table has increased by about 2 m. The comparison of the water level fluctuation in the check dam and groundwater indicate that an area of about 3 km^2 has benefited by raise in groundwater level around the check dam. Based on the water balance calculation it was estimated that this check dam results in recharge of about 1.8 Mm^3 of surface water that is about 66% of the stored water is recharged in to the aquifer. Recharge from the check dam has not reduced during these two years of study due to expected physical or biological clogging. Hence, the check dam across a non-perennial river is functioning efficiently as a method of managed aquifer recharge.

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REFERENCES

Alderwish A.M. (2010): Induced recharge at new dam sites- Sana'a Basin, Yemen". Arab Journal of geosciences, 3: 283-29.

Al-Muttair F. F., A1-Turbak A. S., and Sendil U. (1994): Management of Recharge Dams in Saudi Arabia, Journal of Water Resources Planning and Management. 120(6).

Al-turbak A.S. (1991): Effectiveness of recharge from a surface reservoir to an underlying unconfined aquifer. Hydrology of Natural and Manmade Lakes proceedings of the Vienna Symposium. IAHS Publication no. 206. Online: http://iahs.info/redbooks/a206/iahs_206_0191.pdf. (Accessed 20 Dec 2010)

Ashraf M., Kahlown M.A and Ashfaq A. (2007): Impact of small dams on agriculture and groundwater development: A case study from Pakistan.Agricultural Water Management, Issues 1-2, 92:pp. 90-98.

Bhagavan S., Raghu V. (2005): Utility of check dams in dilution of fluoride concentration in groundwater and the resultant analysis of blood serum and urine of villagers, anantapur district, Aandra Pradesh, India. Environmental Geochemistry and Health, 27:1.

Bijukumar A., and Abraham K.M. (2009): Impact of Peringottukurissi Check Dam On Hydrography Of Bharatapuzha River, Kerala, Journal of Inland Fisheries Society. India.41:1

Charalambous, A.N. and Garratt, P. (2009): Recharge–abstraction relationships and sustainable yield in the Arani–Kortalaiyar groundwater basin, India. Quarterly Journal of Engineering Geology & Hydrogeology, 42, 39-50

Dillon P., Pavelic P., Page D., Beringen H ., and Ward J. (2009):Managed aquifer recharge: An Introduction. Waterlines Rep No. 13.National water commission.

Elango, L., Ramachandran, S. and Sreenivasan, M. (1996). Time series analysis of groundwater quality parameters. Proc., Conf. Hydroinformatics'96, Zurich, pp. 613-620. Muller(ed) Balkema, Rotterdam. ISBN 9054108255.

Gale,I.N.(2006):Managed Aquifer Recharge: Lessons Learned From The Agrar Study, online: (http://www.sahra.arizona. edu/unesco/allepo/Gale.pdf) (Aug 16, 2010)

Gale, I.N., Macdonald, D.M.J., Calow.R.C., Moench, M., Kulkarni, H., Mudrakartha, S., and Palanisami, K. (2006): Managed aquifer recharge: an assessment of its role and effectiveness in watershed Management.Report. No.CR/06/107N.(BGS) Online: http://nora.nerc.ac.uk/7453/1/CR06107N.pdf (Accessed 4 April 2010)

Mudrakartha S. (2003): Augmenting Groundwater Resources byArtificial Recharge Research Site At Aravalli Hills, Gujarat, India.AGRAR Inception Report: Aravalli Case study, Gujarat,VIKSAT.Ahmedabad. Online:

(http://www.iah.org/recharge/downloads/VIKSAT_INCEPTION_REPORT12_May_04.pdf) (Accessed 15 July2010)

Metrowater, Chenai: Surface and groundwater supply to Chennai city. Online: www.chennaimetrowater.tn.nic.in/con-wsy/JNNURM.htm (Accesses 2, September 2010)

Muralidharan D. (2007): Evaluation Of Check-Dam Recharge Through Water-Table Response In Ponding Area. Current science, 92:10

Palanisami K., Raviraj A., and Thirumurthi S. (2006): Artificial Recharge in Hard Rock Areas Of Coimbatore District –A Case Study. International conference on Groundwater sustainableDevelopmentproblems, perspectives and challenges. (IGC-2006). Online: (http://jnuenvis.nic.in/publication/IGC%202006%20Abstracts.pdf) (Accessed 15 June 2010)

Samarah M., Momani M.A., Any,R.T., Jiries A., Naqa A.L.(2009): Evaluation Of Water Quality Of Groundwater Recharge In Wadi Feifa, Southern Jordan Valley . 13th International Water Technology Conference,IWTC 13, 2009,Hueghada,Egypt. Online: http://www.iwtc.info/2009_pdf/13-6.pdf (Accessed 20 August 2010).