World Applied Sciences Journal 3 (6): 963-968, 2008
ISSN 1818-4952

Development of Software Module for Groundwater Recharge

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Abstract: Computer aided techniques are versatile tools in its own towards the direction of precise and readily solutions for the various applied science and technology based problems. Vitality of computer aided techniques have been confirmed in all the streams of engineering and technology and fortunately water resources engineering is also one of the most significant user of such soft techniques for the analysis, design, simulation, modelling etc work. Groundwater engineering and its allied issues in the field of water resources engineering need the use of soft computing techniques for analysis and computation ranging from minor calculation to complex simulation. An attempt is made herewith to focus on such application of soft computing in the computation of recharging of groundwater with rainwater infiltration and groundwater fluctuation method by developing an application software module with front end application in Graphical user Interface Environment.

Key words: Computer aided software module . groundwater recharge . rainfall infiltration . groundwater fluctuation . GEC

INTRODUCTION

Computer-aided outcomes are the use of information technology for availing the rapid, worthy and analytical outcomes for engineers in the successful implementation of technology. Such computer-aided tools may be in the from of simple spreadsheet base template to most complex software which again depends upon the requirements at user end. The most popular computer aided methodologies for providing engineering solutions are presently associated with different streams of information technology like front end application, back end applications, combination of front end and back end applications, objected oriented programming based, graphical user friendly systems, graphics systems, automized system softwares etc. Whatever the stream or problem domain for any engineering stream, the most important aspect is to conceptualization of logic which is to be analyzed, designed and coded in computer software language [1]. Presentation of such conceptualization may be in the form of algorithm, flow chart, UML charts etc. A wide range of such soft computing techniques based module development has been experienced in the stream of Water Resources engineering and Groundwater Engineering under the indigenous head of Civil Engineering. The most widely adapted form of soft computing technique in such mentioned fields is use of graphical user software as front end and database application as back end with further advancement of incorporating the advanced technologies of graphical system for e.g. GIS. Similarly mathematical logic based solutions are coded with such high-level language supported softwares.

GROUNDWATER RECHARGING

Earlier groundwater was considered as an ample quantity water resource with reasonable pure quality, but haphazard exploitation and exploration of groundwater has caused the depletion in the level of availability of groundwater alongwith degradation in groundwater quality. Therefore in such context present era of water resources engineering is constantly attempting in developing innovative approaches of regaining the quantity as well as quality of groundwater. Shared and global efforts of environmental engineering with water resources engineering have developed and employed various methods of recycling and reusing of spent water in conjunction with diverting excess rainwater from ground surfaces in normal and flooded condition as well as from roof top storage to the groundwater strata to *recharge* the level of water and to improve the state of quality in saturated zone of subsurface water. Actually, in sub surface strata aquifers are considered

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as groundwater bearing placeholder with different yields, which again depends upon the geohydrological state [2-4].

Though the recharging phenomenon of groundwater seems to be implemented easily, it needs systematic evaluation and assessment in all respects including detailed investigations of hydrological, geohydrological, meteorological and topographical conditions. Evaluation of groundwater resources essentially involves the quantitative estimation of two components viz.Input flow to groundwater and Output flow from groundwater. In order to evolve proper management strategies and development of groundwater resources of an area, it is essential to quantify all the components of recharge to and discharge from the groundwater reservoir to derive the groundwater balance [5, 6]. The accuracy of finding therefore depends on the reasonability with which these two elements are estimated.In the context of input (Recharge) it is essential to determine the Rainfall infiltration, Recharge from surface water bodies, Return flow from irrigation,Sub surface inflows etc. while Output (Discharge) encompasses groundwater draft, Natural Discharge to streams and subsurface outflow. Determination of such parameters is difficult and a complex task particularly for semi urban and urban areas [7-10].

SOFTWARE MODULE DEVELOPMENT FOR GROUNDWATER RECHARGE COMPUTATION

Being a rapid and accurate solution developer tool, computer aided soft computing techniques have corroborated the successful findings in the field of evaluation of groundwater resources and particularly for the determination of quantity of groundwater for recharging during monsoon and non-monsoon period. Such effort has been attempted here in preparation of software module for the determination of ground water recharging with rainfall infiltration method and groundwater fluctuation method based on the standard Groundwater Estimation Committee (GEC) 1984, Ministry of Water Resources and Government of India. Software module has been developed with Visual Basic – 6.0 as Graphical User Interface with supporting of all API libraries. Module is shaped in likely flexible way and sub module wise to provide computed results of individual sources of recharging. User-friendly menu for the module is designed to differentiate sub modules of recharge computation with rainfall infiltration and groundwater fluctuation method. Each sub modules are presented in separate forms supporting coding in its background and an access to each form is liberalized to refer the parameters and output of other forms. Some

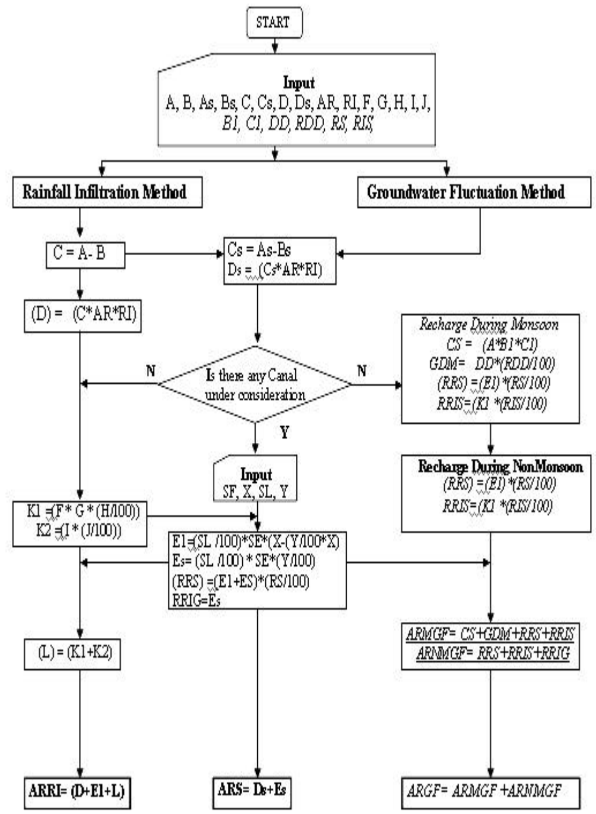

Fig. 1: Flowchart of recharge computation

modules and results have been supported with exception handlers to avoid the fortuitous end of execution of programme module [11, 12].

Framework for module development: Computation of groundwater recharging is a comprehensive work, which needs to integrate various subroutines or sub modules on common platform; however, it becomes necessary to understand the overall recharging computation at conceptualization stage. Such conceptualized can be presented with the tools of system analysis known as Algorithm, Flowchart and UML Diagrams etc. Such tools represent the problem definitions, requirement analysis and logic building collectively in graphical manner to provide easy understanding and systematic flow of logic. Such Computational flowchart for the projected recharge computation work has been prepared on the recommendation and methodologies of groundwater estimation committee in Fig. 1 [9, 13, 14]. Mostly all the required variables for input and process are considered in preparation of software module such variables are shown in Table 1. To avoid the congestions variables are shown only with abbreviations within flowchart however nomenclature of such variables are narrated with Table 1.

Table 1: Variables of recharge computation with rainfall infiltration and groundwater fluctuation method [14]

- Area Occupied by Potable Ground water Resource Excluding Saline area (A)
- Area Not suitable for recharge like built up area and others Excluding Saline area (B)
- Area Occupied by Saline area (As)
- Area Not suitable for recharge like in the area covered by Saline area (Bs)
- Area Suitable for Recharge excluding saline area (C)
- Area Suitable for Recharge within saline area (Cs)
- Annual Recharge due to Rainfall excluding saline area (D)
- Annual Recharge due to Rainfall excluding saline area (Ds)
- Annual Recharge by Seepage (Excluding Saline area) (E1)
- Annual Recharge by Seepage (Saline area)(Es),Average Annual Rainfall (AR)
- Rainfall Infiltration Factor (RI)
- Enter Seepage Factor in M^3/sec per million Km^2 wetted area (SF)
- Estimated Seepage (SE)
- Canal Command Area Covered in Study area or projected area (X)
- Percentage of Seepage loss (SL)
- (Percentage) of area Covered in projected (Y) area by salinity (Saline area)
- Gross Area Irrigated under canals(F)
- Delta (G)
- Percentage of applied irrigation water as recharge(H)
- Gross groundwater draft (I)
- Percentage of Gross groundwater draft as recharge (J)
- Annual Recharge by Irrigation Water (K1)
- Annual Recharge from Ground water Draft (K2)
- Annual Recharge due to Seepage from Surface and Groundwater Irrigation (L)
- Annual Recharge With Rainfall Infiltration Method (ARRI)
- Annual recharge in saline area (ARS)
- Sp. Yield (B1)
- Average Water Level Fluctuation (C1)
- Domestic Draft(DD)
- Recharge Percentage of Domestic draft(RDD)
- Percentage of water as recharge return from seepage(RS)
- Percentage of total recharge from Surface water Irrigation (RIS)
- Change in Storage (CS) Groundwater Draft Monsoon)(GDM)
- Return seepage due to surface water applied for irrigation for the monsoon (RRS)
- Recharge due to recycled water from surface water Irrigation during Monsoon (RRIS)
- Recharge due to recycled water from ground water Irrigation during Monsoon (RRIG)
- Annual Recharge During Monsoon With Groundwater Fluctuation Method (ARMGF)
- Annual Recharge During Non-Monsoon With Groundwater Fluctuation Method ARNMGF)
- Total Annual Recharge with Groundwater Fluctuation method (ARGF)

Fig. 2: Location map showing study area

Screenshots of working modules for study area: Recharge computation has been carried out with the base of native logic as mentioned in Fig. 1 and such basic is programmized with well-known front-end graphical user interface programming language Visual Basic. Surat Urban Development Authority (SUDA) area has been taken for the module execution as study area and all relevant information for the study area has been collected from standard concern sources and few years back records, according to which Surat city in India has grown rapidly within since last decade due to fast urbanization trend and own importance of Surat city.

Due to fast development and population growth the area beyond Municipal authorities of Surat City known as Surat Municipal Corporation (SMC) has also developed. To develop the area beyond SMC in a well-planned manner, SUDA was formed under Gujarat Town Planning and Urban Development act-1976.SUDA area forms the western border of Surat District and lies between latitudes of 21º03’N-21º19’N and longitudes 72º41’E-73º00’E which covers 722 km^2 area including SMC and area of 148 villages surrounding SMC how ever at present stage some of the villages in SUDA have been covered in SMC Limits within expansion strategies of Municipal Limits [4]. Some Screenshots of software module of recharge computations are shown in subsequent Fig. 3 and 4.

Salient features of software module

- Module is available in Package form for easy installation on windows based software system Software Module is Graphical user friendly.
- Coverage of Sub modules on common canvas called MDI Form
- Easy access to other sub modules of forms with-out interfering the current module.
- Reusability of calculated variables and value.

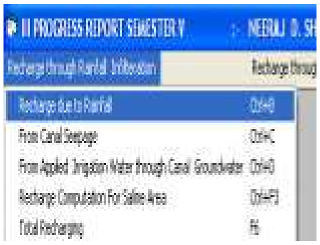

Fig. 3: Screen shots of menu and submenu contents of software module

- Public access of variables in more than one module.
- Easy reference of output of one sub module for another
- Point and Click Environment
- Provision of Shortcut Key for direct access & Direct copy of data/information from one module to another [12]

Future prospective with module: Present software module has covered only the calculative part of recharge computation and the outcomes of such computations are only visible to user for the determining the Net recharge by consideration both the well known method of groundwater recharge computation, however results are not being saved at some database or another location so by looking the potential of subject following further prospectives may be extended to this software module [11, 12]:

- A Database system can be designed and implemented to store the results obtained by both the methods by designing most consistent database system having the data table configured with all relevant fields
- Most advanced query builder can be developed by providing interrelationship of databases or data tables
- Database development may give alternatives for modification in involved variables and on virtue of this groundwater recharge can be compared with different regions of country as well as different area of same region
- Addition of Report Writer Component can be supplemented to the module to provide hard copy results as well as to impart the group field wise results.

MODULE INPUT-OUTPUT FOR STUDY AREA

Results have verified with manually computed recharge values and same figures have been found with computed results from software module [15]. Input and Output from the available data of study area is tabulated in Table 2.

Table 2: Input and processed output for data of study area

Input parameters for study area	Output for study area
A = 580 Km^2, B= 20 Km^2	C = 560 Km^2
As = 142 Km^2, Bs=32 m^2	Cs = 110 Km^2
AR = 1201.9 mm	K1 = 85.80 MCM/Year
RI = 0.10	K2 = 15.14 MCM/Year
SF = 2.38 $m^3/sec/10^6 m^2$ wetted area	L = 100.94 MCM/Year
SE = 430.76 MCM/Year	ARRI = 206.50 MCM/Year
X = 379000 Hectares	ARS = 17.47 MCM/Year
SL = 50%	CS = 133.60 MCM/Year
Y = 10%	GDM = 18.7 MCM/Year
F = 188.56M^2	RRS = 21.25 MCM/Year
G = 1.30 Mt	RRIS = 42.90 MCM/Year
H = 35%	RRIG = 15.14 MCM/Year
I = 50.48 MCM	ARMGF=156.27 MCM/Year
J = 30%	ARNMGF= 79.29 MCM/Year
B1 = 0.10	ARGF = 219 MCM/Year
C1 = 1.85 Mt	
DD = 36.5 MCM	
RDD = 50%	
RS = 50%, RIS = 50%	

with the use of such software module an analysis for the variation in recharge computation with variation in yearly rainfall is carried out and because such module works with bundled logic of GEC which ultimately at the end of computation counts the percentage deviation between the results of the both the methods (Rainfall Infiltration and Groundwater Fluctuation Method) and as per that it reflects the results so here average annual rainfall is take as 1201.6mm and for the annual rainfall range of 500 mm, 800 mm, 1000 mm, 1200 mm and 1400mm recharge is computed alongwith three cases having the rainfall infiltration factor (RI) value 0.1,0.2 and 0.3 respectively and the computed recharges are plotted in Fig. 5 where it has been noticed that as infiltration factor increases the variation in the value of computed recharge decreases which is inherent in the logic of percentage Deviation given by GEC. The results from the above two methods (water table fluctuation and rainfall infiltration method) are compared using Percent Deviation using the following relation [8, 13, 16, 16]:

$$P.D. = 100 \times (R_{rf}^{wtf} - R_{rf}^{rif}) / R_{rf}^{rif} \qquad (1)$$

where,

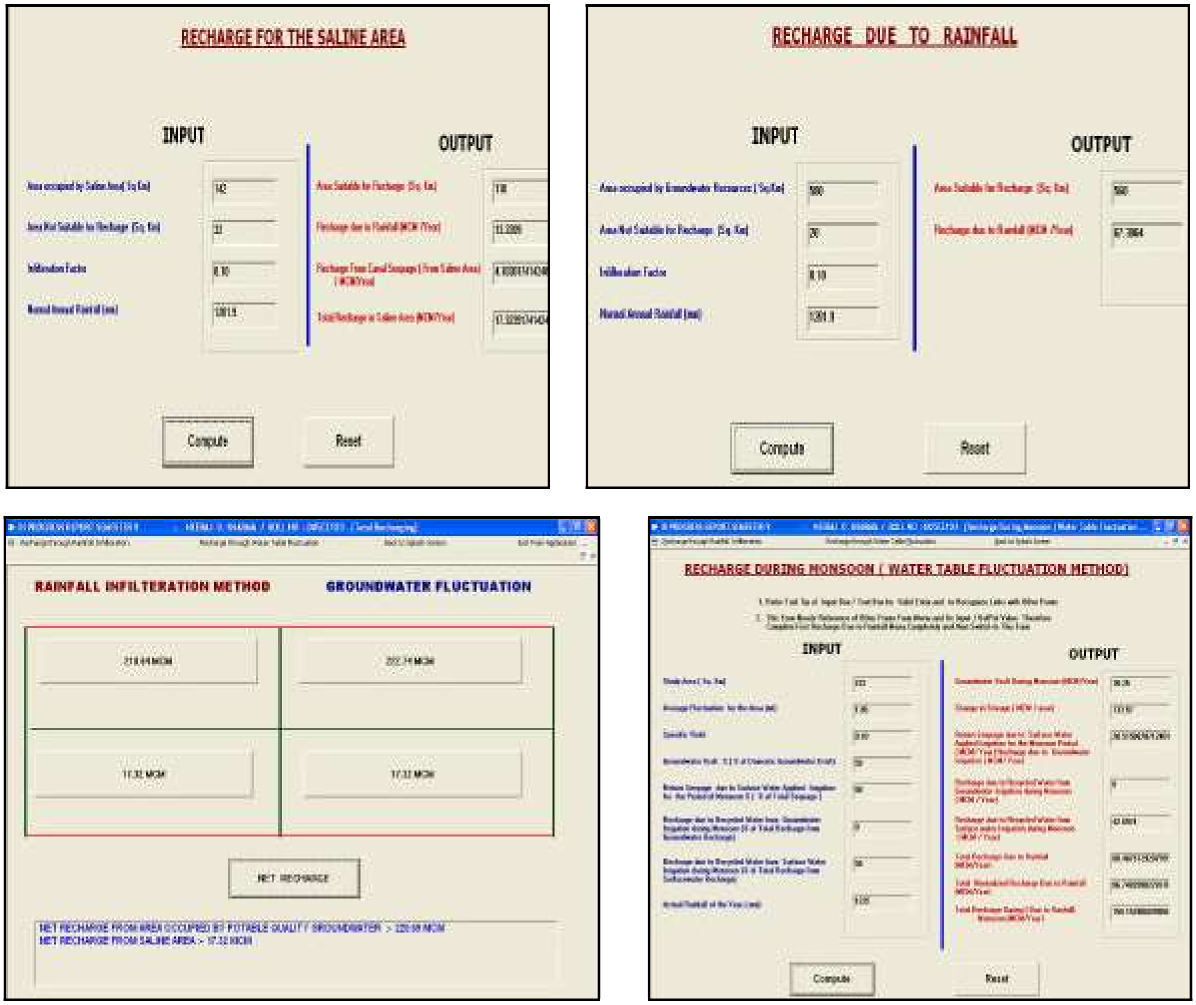

Fig. 4: Screen shots of various modules of recharge computation and showing net recharge with groundwater fluctuation method in monsoon and net recharge display

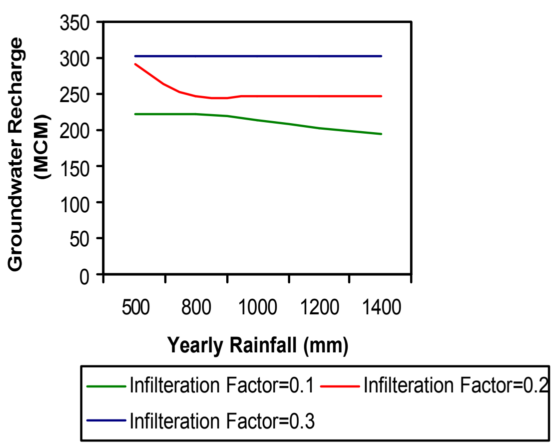

Fig. 5: Chart showing the variation in computed recharge with yearly rainfall variation for given infiltration factors

P.D. = Percent Deviation

R_{rf}^{wtf} = Recharge from Rainfall (Normalised) as computed by Water Table Fluctuation Method

R_{rf}^{rif} = Recharge from rainfall as computed by Rainfall Infiltration Factor Method.

Finally Recharge from Rainfall is computed by adopting the following criteria [6, 16]:

If – 20 = P.D = + 20 then $R_{rf} = R_{rf}^{wtf}$

If P.D. < – 20 then $R_{rf} = 0.8 * R_{rf}^{rif}$

If P.D. > + 20 then $R_{rf} = 1.2 * R_{rf}^{wtf}$

CONCLUSION

Groundwater Recharge Estimation is found perceptive phenomenon which depends upon many interrelated parameters and varies place to place and time to time. The computation of recharging is calculative efforts which needs concentrative analysis and reckoning task which can be better solved precisely and fast with the help of computers and particularly GUI Software provides more flexible approach for designing and presenting such recharge computation which not only works as calculation modules but the effects of variations of various dependent parameters in computation can be evaluated and presented comparatively. Among various methods of computation, Rainfall-Infiltration and Groundwater Fluctuation methods are found as the most practical and feasible approaches for such recharge computation task and due to such fact these methods are most popular in India as well many other parts of the world.

Outcomes of recharge computation from SUDA area in Surat, India with such developed software module has been compared with manually calculated and presented values where mostly values are found with close proximity.Same data can be used with same software module towards the direction of microanalysis like impact of variation in one or more input data on recharge volume however module needs further extensions to become widespread solution. Such developed module can become significant tool in providing data of recharge to the simulation and modelling task of groundwater.

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