Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 08, pp.55589-55592, August, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

SURFACE WATER- GROUNDWATER INTERACTION MODELLING APPROACHES & THEIR SUITABILITY FOR INDIAN CONDITIONS

[1, *]Vihang G. Pathare and [2]Dr. Seema A. Jagtap

[1]Yadavrao Tasgaonkar College of Engineering and Management, Bhivpuri, Karjat, India
[2]Head of Civil Department, Thakur College of Engineering and Technology, Mumbai, India

ARTICLE INFO

Article History:
Received 27th May, 2017
Received in revised form
23rd June, 2017
Accepted 05th July, 2017
Published online 31st August, 2017

Key words:

Groundwater,
Surface water,
Modelling.

ABSTRACT

This paper is a thorough literature review of processes related to surface water and groundwater interactions and the available tools to model them at various spatial and temporal scales with different levels of complexity. This paper aim to put light on exchange fluxes between surface water-groundwater for rivers in India and predict how these may change with existing or different surface water and groundwater management. As such, this address a major recognised deficiency in the management of troubled or vulnerable Indian catchments in accounting for stream- groundwater interaction in the water budget. It is aimed at determining the deficiencies of the present modelling approaches for Indian conditions and highlighting scope for future model development. It is intended to enhance awareness of the different modelling approaches published in the peer-reviewed literature, prevent duplication, and underpin adaptation and initiate informed debate.

Citation: Vihang G. Pathare and Dr. Seema A. Jagtap, 2017. "Surface water- groundwater interaction modelling approaches & their suitability for Indian conditions", *International Journal of Current Research*, 9, (08), 55589-55592.

INTRODUCTION

There has been an ample magnitude of follow-up done abroad and within India on the processes affecting surface water-groundwater interactions. These processes can be complex and include, flooding recharge, evapotranspiration from shallow water tables, groundwater interception by wetlands, Para fluvial flow, hyporheic exchange, bank storage, effects caused by fluctuating river levels, groundwater extraction, structural features causing heterogeneity of flow. Techniques have been improved to evaluate and model these processes at a range of spatial and temporal scales. However, it is unclear how relevant these methods are to Indian conditions, which have a unique landscape setting and an often-sparse availability of surface water and groundwater data.

THEORY

Three Level of Model Complexity

Level 1: 1st order lumped parametric models based on empirical relations derived from numerous field observations or concepts.

Level 2: 2nd order models that operate at finer temporal and spatial scales compared to 1st order models and have a more conceptual resolution and process complexity.

Level 3: Process based, distributed, deterministic models.

Model Design Norm and its Appropriateness

The spatial scale at which a model is applied dictates its level of complexity and hence what processes are considered for it. Large scale models usually adopt a lumped approach that requires less parametrisation whereas small scale physically based models can without disguise account for more processes. Distinguishing the spatial property dimensions of any difficulty is of utmost importance as model complexity varies in an exponential manner with model dimensionality. (a 10-element 1-D model, has 100 elements in a 2-D model, and 1000 elements in a 3-D model). Data requirements are clearly related to model complexity and the spatial scale at which the model generates. Lumped models require less data whereas process-based models require much more data. In many cases, model selection is confined by data accessibility. At a whole-of-river scale, readily available data can support low fidelity modelling whereas infernal measurements at a sub-reach level may be necessary to sustain high fidelity modelling; this directly impacts field experimental design. When selecting modelling tools for surface water- groundwater interaction, it is vital to cause the right balance between surface water and sub-surface water processes. Clear definition of the problem

---

****Corresponding author: Vihang G. Pathare,***
Yadavrao Tasgaonkar College of Engineering and Management, Bhivpuri, Karjat, India.

and identification of any accentuation on surface water- ground water processes have a close correlation on the outcome of model selection. The remit of temporal scale becomes crucial when modelling surface water- ground water interactions, as surface water processes are quick whereas, ground water processes are much more attenuated. Large time limping in measuring a process may mask other processes that may occur during short periods as a result of the averaging effect of large time interval data. Large disparities in time steps between surface water and groundwater may lead to numerical instabilities. Other remittances that affect model suitability are whether software packages (and their source codes) are freely (or at reasonable cost) available or not. Another vital criterion is the availability to develop the model within the time framework.

Modelling Approaches

The selection of a modelling tool is hugely influenced by its ability to model various processes relevant to surface water-ground water interaction.

Groundwater Driven Processes: Stream Depletion

Pumping induced stream depletion is defined as the reduction of stream flow due to infiltration of stream water into the aquifer or the possession of aquifer discharge to the stream (Sophocleous 1997; Theis 1941). The problem of stream aquifer interaction is relevant to conjunctive use management of water resources and riparian zone hydrology (Hantush 2005). This concept is only pertinent to streams connected to aquifer via a fully saturated material.

Analytical Modelling

There are numerous analytical solutions for stream depletion derived for a variety of conceptual systems for pumping. Theis (1941) obtained the first unsteady solution for the stream depletion due to abstractions from a fully penetrating well. Glover and Balmer (1954) re-wrote the Theis solution terms of complementary error function. Singh (2000) showed that the two analytical solutions are the same in the mathematical sense by solving the integral in the Theis solution to arrive at the solution of Glover and Balmer. From this studies it can be inferred that:

- An increase in stream width results in increasing stream depletion.
- The effect of increase in the stream width becomes limited due to increase in the length of ground water under the stream.
- When the stream leakage is large, the stream depletion curves approach the case of a fully penetrating stream.

Surface Water Driven Processes

Overland flow and through flow

The stream flow response to precipitation is dependent on the flow pathways of the watershed, which include direct (on-stream) rainfall, overland flow, through flow or shallow sub-surface flow, and groundwater flow. Overland flow is described as the water that flows over the surface either as quasi-laminar sheet flow or as flow conjugation in trickles and rivulets, while through flow (or interflow) refers to sub-surface flows that travel laterally to streams through unsaturated soil and in 'perched' saturated zones. In deterministic hydrological models, surface flow hydrographs are usually generated using lumped or semi-distributed (i.e. lumped at the sub-basin scale) catchment models that are calibrated to stream gauge data, where available. An alternative to deterministic modelling is the stochastic approach, which comprises time scale analyses of rainfall and stream flow records to investigate hydrological event frequency. Various methods of catchment runoff appraisal exist and these includes:

- Numerous variations of the unit hydrograph approach.
- Catchment storage routing methods.
- Distributed models.

River Flow Attenuation

Storage effects in rivers affect the transition of flow events, can be evidenced by the re-distribution of stream flow hydrographs at successive points along a river. Hydrograph attenuation is characterised by a reduction in peak flows and an increase in time lag. It depends on the volume of the stream flow event compared to the volume of storage, and on the physical attributes of the system such as length, slope and hydraulic resistance. The diligence of the timing and magnitude of flow at points along a watercourse from upstream hydrographs is referred to as 'flow routing'. In hydrologic studies, flow routing generally assumes a lumped representation of the system, whereby flow hydrographs are calculated only for typical locations. Hydrological routing methods solve the continuity equation using simplifying relationships between the channel storage (S) and flow (Q) or the time derivative of flow (dQ/dt). Some of the methods are Level Pool method, Muskingum method, the Linear reservoir model and the Modified Pulse method.

In-stream Storages and Reservoir Operation

In terms of stream flow events, increasing the in-stream storage enhances the river flow attenuation, i.e., reduces peak flows and increases time-lags. The modelling of the effects of in-stream storages on hydrographs can be ascertained using Level Pool Method. Finding the influence of in-stream storages on the low flow hydrology (including stream-aquifer interaction), rather than the flood hydrology, of a river is more complex, and is highly dependent on the regulation of dam releases, and the attributes of the storage reservoir.

Off-Stream Storages

All dams are subject to seepage, either through the foundation and abutments, or through the embankment itself in the case of earth and rock-fill dams. Few studies have expedited the influence of seepage from off-stream storages on both groundwater hydrology and groundwater-surface water interaction. Surface water impoundments can be used to increase groundwater storage through artificial recharge that results from reservoir seepage.

Bank Storage

During inter-storm periods, there is a stream-ward hydraulic gradient in gaining streams that sustains groundwater discharge into them. Stream water levels rise in response to runoff, and, in most cases, results in the reversing of the hydraulic gradient, which includes a net flux into the floodplain. This water is temporarily stored in the floodplain and is slowly released back to the stream when the stream water level drops and the gradient towards the stream is re-established. This phenomenon is referred to as bank storage. Significant bank storage occurs when:

- A stream is subject to storage increases.
- Bank materials have a high hydraulic conductivity.
- Sufficient volumes of permeable bank material provide storage.

Over-Bank Flooding

Two important elements contributing to the water budget of an aquifer are recharge and stream aquifer interaction (infiltration and exfiltration of water across the stream bed). Over-bank flooding is a crucial hydrologic process influencing water table dynamics and ecological processes such as bio-geochemical cycling and plant diversity. Over-bank flooding usually takes place for a few days to weeks on average after years for most rivers. Soil water and groundwater recharge can be greater during over-bank flooding than from river aquifer interactions and precipitation.

Surface Water- Groundwater Interaction Driven Processes

Wetlands cover approximately 6% of the world's land area, their effect on the water cycle is significant. Wetlands can be defined as, 'land transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water'. Wetlands includes swamps, marshes, lakes, salt marshes, mudflats, mangroves, coral reefs, ferns, bodies of water-whether natural or artificial, permanent or temporary. Water within these areas can be static or flowing, fresh, brackish or saline. The main components of wetlands hydrology are: precipitation, influent river seepage, over-bank floods, and groundwater inflow; outflows includes: evapotranspiration, effluent river seepage, surface runoff, and groundwater outflow. The hydrology of wetlands is largely controlled by their position in the groundwater flow system. (Todd et al); the interactions of wetlands with groundwater and surface water are also affected by the geologic features of their beds, and their climatic settings.

Evapotranspiration

Potential evapotranspiration (PET) is defined as the amount of water that can evaporate and transpire from a vegetated landscape without confinement other than the atmospheric demand. Gauging actual evapotranspiration (AET) in moisture stressed settings is usually inferred using a parameterised AET sub-model of the hydrologic model. AET can be simulated in different stages of complexity, which mainly depends on the complexity of the hydrologic system being simulated and the accessibility of data. Hydrologic models need spatial and temporal quantification of flows of water into, out of, and within the hydrologic system. The importance of AET within the water budget demonstrates that this flow must be assessed in most hydrologic models. The difference between AET and precipitation gives the 'available water' for recharging aquifers and streams, and with any change of two members (particularly if the two are comparable in quantity), relative error can be magnified, which further sustains the need for the best evaluation of AET. Quantification of AET is vital to the water resource management because it accounts for alarge share of water budget. Across the globe, AET returns about 64% of land based precipitation to the atmosphere. Transpiration from groundwater creates cones of depression that cause surface water to seep into the neighbouring aquifer. Direct evaluation of AET provides an chance to improvise the quality of hydrologic model calibration through reduction in the uncertainty of the AET component of the model in one of the two ways:

- Prescribing the AET input in the model to the measured values.
- Comparison of the AET values inferred through the AET sub-model with the measured values.

DISCUSSION AND SUMMARY

To select the right modelling tool, we need to have conceptualised our problem correctly, this clearly means that we know beforehand the processes involved and how they interact with each other. The next step is then developing a modelling tool with the ability to model these processes at the required spatial and temporal scales. The latter is closely related to the processes themselves; for example, surface water processes are fast whereas groundwater processes have a much slower response time. The spatial scale dictate the level of model complexity where larger scale models usually adopt a conceptual approach and smaller scale models adopt a more physically based approach. Small models require much more data than the large-scale models. The landscape setting where the model is being applied has an important effect on model selection. For example, modelling water flow in fractured media require dual-porosity models; layered systems require models that can handle heterogeneity and landscapes with large flat floodplains need a incorporating evapotranspiration and overbank flooding.

Deficiencies of Present Models

The surface water-groundwater interaction processes are poorly handled in existing surface water models and ground water models. In river models, this interaction is simplistically modelled as a boundary condition. More elegantly models that precisely account for the surface water- groundwater interaction usually require more data, which is not always available. Moreover, such models require a very high degree of modelling expertise, which is not always available in water management agencies. Identifying the surface water-groundwater process that are most relevant to the Indian landscape is very crucial. To strike the right balance between surface water processes and groundwater processes, special purpose in-house models should be developed.

In most scenario, model selection is restricted by data availability. Data requirements are closely related to model complexity and the spatial scale at which the model operate. Simple models that require less data and are tailored for the Indian landscape should be developed. The spatial scale at which a model is applied dictates its level of complexity and have what processes are accounted for large scale models usually adopt a lumped approach that requires less parameterisation whereas small scale physically based models explicitly account for more processes.

Conclusion

'Surface water- Groundwater Link' model operates as a river link to groundwater models and enhance the performance of river models by accounting for the effects of surface water-groundwater interactions that are likely to take place along a river basin. 'Flood Plain Processes' model dynamically models bank storage, evapotranspiration, and floodplain inundation. The expected outcome is modelling the surface water-groundwater interactions at the sub-river-reach scale with higher resolution and the capacity to link to ecological response time.

REFERENCES

Abu-Taleb, M.F. 2003. Recharge of groundwater through multi-stage reservoirs in a desert basin. Environmental Geology 44: 379-390

Hantush, M. 2005. Modelling stream aquifer interactions with linear response functions. Journal of Hydrology 311: 59-79

Lin, Y.C and Medina, Jr M.A. 2003. Incorporating transient storage in conjunctive stream-aquifer modelling. Advances in Water Resources 26: 1001- 1019

Theis, C.V. 1941. The effect of a well on the flow of a nearby stream. American Geophysical Union Transactions 22: 734-738.

Todd, G.K. 1955. Groundwater flow in relation to the flooding stream. Proceedings of the American Society of Civil Engineers 81: 628-1-628-21

Wikipedia

www.google.com

****