GLOBAL JOURNAL OF HUMAN-SOCIAL SCIENCE: B
GEOGRAPHY, GEO-SCIENCES, ENVIRONMENTAL SCIENCE & DISASTER MANAGEMENT
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-460X & Print ISSN: 0975-587X

The Move from Safe Yield to Sustainability and Manage Yield

By Yohannes Yihdego & Muhammad Waqar
Snowy Mountains Engineering Corporation

Abstract- There is currently a need for a review of the definition and methodology of determining sustainable yield. The reasons are: (1) current definitions and concepts are ambiguous and non-physically based so cannot be used for quantitative application, (2) there is a need to eliminate varying interpretations and misinterpretations and provide a sound basis for application, (3) the notion that all groundwater systems either are or can be made to be sustainable is invalid, (4) often there are an excessive number of factors bound up in the definition that are not easily quantifiable, (5) there is often confusion between production facility optimal yield and basin sustainable yield, (6) in many semi-arid and arid environments groundwater systems cannot be sensibly developed using a sustained yield policy particularly where ecological constraints are applied. Derivation of sustainable yield using conservation of mass principles leads to expressions for basin sustainable, partial (nonsustainable) mining and total (non-sustainable) mining yields that can be readily determined using numerical modelling methods and selected on the basis of applied constraints. For some cases there has to be recognition that the groundwater resource is not renewable and its use cannot therefore be sustainable. In these cases, its destiny should be the best equitable use. We suggest using the term Managed Yield as an alternative to Sustainable Yield to clarify the ambiguity among stakeholders.

Keywords: groundwater, conjunctive use, sustainable yield, safe yield, sustainable development, mining yield, water budget, recharge, storage depletion, groundwater management.

GJHSS-B Classification: FOR Code: 040699

THEMOVEFROMSAFEYIELDTOSUSTAINABILITYANDMANAGEYIELD

Strictly as per the compliance and regulations of:

OPEN ASSOCIATION OF RESEARCH SOCIETY, USA
RESEARCH | DIVERSITY | ETHICS

The Move from Safe Yield to Sustainability and Manage Yield

Yohannes Yihdego [α] & Muhammad Waqar [σ]

Abstract- There is currently a need for a review of the definition and methodology of determining sustainable yield. The reasons are: (1) current definitions and concepts are ambiguous and non-physically based so cannot be used for quantitative application, (2) there is a need to eliminate varying interpretations and misinterpretations and provide a sound basis for application, (3) the notion that all groundwater systems either are or can be made to be sustainable is invalid, (4) often there are an excessive number of factors bound up in the definition that are not easily quantifiable, (5) there is often confusion between production facility optimal yield and basin sustainable yield, (6) in many semi-arid and arid environments groundwater systems cannot be sensibly developed using a sustained yield policy particularly where ecological constraints are applied. Derivation of sustainable yield using conservation of mass principles leads to expressions for basin sustainable, partial (non-sustainable) mining and total (non-sustainable) mining yields that can be readily determined using numerical modelling methods and selected on the basis of applied constraints. For some cases there has to be recognition that the groundwater resource *is not* renewable and its use cannot therefore be sustainable. In these cases, its destiny should be the best equitable use. We suggest using the term Managed Yield as an alternative to Sustainable Yield to clarify the ambiguity among stakeholders.

Keywords: groundwater, conjunctive use, sustainable yield, safe yield, sustainable development, mining yield, water budget, recharge, storage depletion, groundwater management.

I. INTRODUCTION

Ground water systems conservation is a major challenge of this century, but their importance from a human perspective lies mainly in the functions and services they provide; Groundwater systems are important, which needs to maintain in sustainable future (Devlin and Sophocleous 2005; Yihdego et al. 2017; Yihdego and Becht 2013). The water function and services are not unique for groundwater systems and may be provided by other water system components as well. This is in particular the case for the water supply function: in most regions one may choose between groundwater and surface water, or even desalinized seawater and non-conventional sources such as treated waste-water, as alternative sources for satisfying the same water demand The resource exploration and its management has directional horizons e.g. increasing or decreasing. Groundwater development and management should be viewed in an integrated water resources management perspective, or even in a broader regional development context. Management aspect of ground water is difficult and have to develop on scientific grounds due to an increase in ratio of groundwater usage to groundwater availability. In this scenario over exploitation and long term capacity of aquifer is big question to solve because the capacity of aquifer is reducing continuously due to over exploitation (Custodio 2002). The key question then is not whether the development of a particular groundwater system is sustainable, but rather whether the complex of natural resources (to which that groundwater system belongs) allows and supports sustainable socio-economic development and preservation of desired environmental conditions in the region

The actual abstraction is significantly less than the theoretical proposed and calculated, there are cases where it has assessed that the abstraction exceeds the long-term capacity of the aquifer. In Australia for example, the total 538 Groundwater Management Units nationwide examined during a national water audit in 2000, 57 are regarded as being pumped at a rate that exceeds their long-term capacity (Kalf and Woolley 2005). Water resource managers have sought to redeem the situation by reducing the volume allocated, and in some cases the volume pumped, to a level that they have assessed is “sustainable” (Kendy 2003; Sophocleous 2005; 2007; Yihdego and Webb 2011; Yihdego and Drury 2016a, 2016b; Yihdego and Paffard 2016).

The debate has developed about the way in which the “capacity” of an aquifer to deliver water to sustainable end that should be defined and determined quantitatively and qualitatively. As ramification two prominent concepts were developed first Safe Yield and much later Sustainable Yield. These concepts together with a variety of applied constraints constitute what has been called “sustainable groundwater development”

Author α : Snowy Mountains Engineering Corporation (SMEC), Sydney, New South Wales 2060, Australia.
e-mail: yohannesyihdego@gmail.com
Author σ : College of Earth and Environmental Sciences University of the Punjab Lahore, Pakistan.

(Hiscock et al. 2002). If the concept of sustainable groundwater development is to be applied, then it is essential that both safe yield and sustainable yield be understood. Unfortunately, this is currently not the case and there is a variety of interpretations and often also confusion as to their exact meaning (Sophocleous 2005; Yihdego et al 2016a, 2016b).

This paper re-examines the concept of sustainable yield. It seeks to provide a scientific way of redefining these concepts, rather than a specific word definition, further explanation for practitioners and water resource managers who has concern with dynamic ground water system. Because the dynamic ground water system could be defined without the sound basis of ground water quantification concept. Another objective is to rephrase the concept on a sound scientific ground sin the light of fundamental groundwater principles. Most of the concepts outlined in this paper are not new because they have been retrieved from the available literature, based on intention to develop a new perspective as a way of reminding water resource managers and others that fundamental principles should not be overlooked as they seek to show that use of natural resources is sustainable. The reason is that ground water resources have different worth as compare to other natural resources.

This paper begins by first referring the long historical development of yield definitions to place their meaning into context, provide some examples of concepts used in a number of countries, and to outline some of the ambiguities of sustainable yield definitions. This is followed by a derivation of basin sustainable yield based on conservation of mass principles and applied constraints, and a discussion of the implications of some practical issues.

Some examples of sustainable and non-sustainable yield assessment are followed by a listing of some considerations relevant to groundwater management and concepts presented, and conclusions.

II. DISCUSSIONS

a) Development of Safe Yield concept

The safe yield concept has originated with prime attention to environment and unwanted declining of water table. At first this concept was based on capacity of aquifer and its size reduction without defining its spatial aspects. Lee (1915) was first who define the safe yield as maximum quantity of water that could be withdraw from ground water system without producing the unwanted results to aquifer. Soon after him Meinzer (1923) has defined safe yield as rate of maximum output of aquifer to human being. It seems that the Meizer has discussed only the economic aspects of ground water system. After that Conkling (1946) and Banks (1953) has discussed the water quality and water rights concept. Further addition was made by Todd (1959) in safe yield concept as "it is amount of water that can be withdrawn annually without producing undesired results".

With the passage of time safe yield concept further manipulated but Thomas (1951) Kazmann (1956) have inhibited this definition because of misconstruction, vagueness, static and dynamics difference of ground water system. Although this definition of safe yield still in use ignoring other relevancy to ground water system but still yield quantification required to improve it further. Another ambiguity linked with maximum and minimum limits of safe yield is still unstipulated (Calo wet al. 2010 and Mukherji 2008).

Many suggestions for improving the safe-yield concept have focused on considering the yield concept in a socioeconomic sense within the overall framework of optimization theory. The optimum yield is determined by selecting the optimal management scheme from a set of possible alternative schemes. Of course, within such a framework, consideration of present and future costs and benefits may lead to optimal yields that involve mining ground water, perhaps to exhaustion.

A common misperception tailored that the development of ground water system is safe if the average annual rate of ground water withdrawal does not exceed the average annual rate of natural recharge. Brede hoeft (1982) and Bredehoeft (2002) give examples of how safe development of aquifer depends instead on how much of extraction can be captured from increased recharge and decreased discharge. Sophocleous (1997) and Bredehoeft (1997) have further elaborate that for safe yield the quantification of recharge should be greater than discharge on contrary discharge increase will not hold safe yield concept.

b) Development Sustainable yield

The sustainable concept is developed in early 1980s with centered idea of limited availability of resources and how to regenerate for coming generations. Proper definition of was given by Brundtl and commission (1987) which was also known as world commission on environment and development that is "to meet the needs without compromising the future generations. Then United Nation (1992) has put forward the concept of sustainability. This idea is based on integration of environmental and development apprehensions. Further it is highlighted in recent World summit that sustainability is concept which deals with resources quantification.

The water resources sustainability is different as compare to other natural resources. It is also crucial to define water sustainability, because it is vitally linked with existence of human being and according to some estimation more than 0.783 billion people will not have safe drinking water by 2050 (Gleick 2001). Like the concept of safe yield, sustainable yield is also expressed in broader extent which make somewhat ambiguous due to applied constraints. Holistic view of sustainable yield may be valuable to some environmental economic aspects but in water resources it is defined within the confined framework which is not elaborating water resources in detail due to broader spectrum (Sophocleous 1998; Alley et al. 1999; Sophocleous 2000). Although it is tried to explain sustainable yield in similar lines of safe yield concept but it is still ambiguous due to dynamic ground water system and its development.

The major challenge of this era is to define sustainability due to its versatile scope (UNESCO 1999; Loucks 2000). Some ambiguities attached with sustainability concept due to its philosophical framework (Norton and Toman 1995). For example, the use of resources will be differed from ecologist to economist due to their perspectives of ecosystem existence and profit generation or else. And also economist will think about non declining end of his capital stock and will seek the relation between strong and weak sustainability of his resources.

c) The managed yield concept and its justifications

The safe yield and sustainable yield concept could not be fully implemented to ground water system due to its complex structure and applied constraints attached with it. Sustainability concept related to ground water resources is more concern with safe yield. Because of dynamic nature and anthropogenic intrusion along with land use change (Alley et al. 2002). Safe yield has functional relation with water withdrawal and its temporal pattern while the sustainable yield caters long term availability of water resource through replenishment in dry season and withdraw in wet season.

Sustainability is a very complex concept. Its practical interpretation depends on the systems considered, the angle of view, the overall local context and subjective comparisons between alternative futures. Applied to groundwater abstraction, it makes a difference whether one has sustainable pumping in mind or the sustainability of the local society and ecosystems. In the latter perspective, even unsustainable pumping from a non-renewable groundwater resource might contribute to sustainable development, provided that other water resources are available to meet water demands on the long run, after the non-renewable groundwater resource will be exhausted. Furthermore, the extent of storage depletion due to pumping may vary from case to case, and the same is true for the impacts of storage depletion. Such impacts tend to be more severe in arid than in humid climates, because buffering by other components of the water cycle there is less likely to occur.

Sustainable yield has not enough to justify ground water in dry and wet periods, per capita water demands, withdraw management, impacts of renewable fluxes (base flow intrusion), runoff recharging variables, ground water stress estimation, subsurface anomalies, spatial and temporal pattern of ground water availability, social issues, environmental problems, legal aspects, chemical parameters, physical and biological variables, water demand and supply, anthropogenic variables and climate change scenarios. Sustainable yield put forward by considering water as capital which could be maximized and optimized for future that seems less practical.

We are agreeing that water is natural resources and it may have been considered as renewable resources in past but growing population has changed this approach. According to UNDESA 2015 world population will grow up to 9.7 billion by 2050 which will put pressure to ground water system to withdraw more water to meet the increasing demand of masses. It would become difficult to define per capita water availability due to limited resources of water. This upsurge of population will also become a reason for growing urbanization which will further reduce the natural replenishment of ground water system.

We may consider of ground water as partial renewable resource due to reduction of recharge and increase in discharge from ground water system due to negative impacts of physical, social, environment and legal variables. So to secure ground water for our future we don’t need to sustain on philosophical agreements but we need to develop out ground water resources in a managed manner. We can manage it by making the controlled with drawal of water from system and maximizing input to system for replacement. Stress analysis should be done to optimize the availability of water in managed way. Quantification and qualification may also be achieved through strict management and policy making efforts. Furthermore, subsurface anomalies will be treated in technical way with its spatial, temporal and trans boundary aspects. Anthropogenic and climate variable may be adopted in a managed fashion to avoid future uncertainties.

In view of above discussions, we may conclude that “managed yield” is more sophisticated term instead of using the safe yield or sustainable yield. Because we only manage the ground water availability in the long run ignoring the undesired effects on water table. It is very difficult to apply the sustainability concept to ground water system due to its complexity, dynamic nature, quantification aspects and spatio-temporal variability.

III. CONCLUSIONS

The safe yield concept was developed the idea of water withdrawal from ground water system while the sustainable yield concept was developed on optimization of resources by considering water as capital resource. But practical simplicities attached to these concepts are ambiguous and misinterpreted t of ground water system e.g.the recharging and discharging in growing population and technical variables.The sustainable yield conceptis more economical, social, and legal in nature while safe yield considered only technical aspects of ground water system. In view of both concepts either safe yield or sustainable yield cannot define the ground water system alone, therefore a sophisticated approached is required to explain system regardless all ambiguities

In addition to sustainability concept interpretation, whether one is able to cope with certain physical impacts of ground water mining varies according to the local conditions. Wealthy developed societies with good access to financial resources and technology are in this respect in a more favorable position than poor developing countries. Whatever perspective is chosen, it is clear that groundwater development always comes at a cost (environmental, financial or otherwise). It is up to society to decide whether this cost is balanced or outweighed by the benefits of the abstracted groundwater and does not threaten sustainable development. In order to underpin such a decision adequately, it is important to have a good picture of the groundwater system considered, to understand its response to pumping (avoiding the water budget myth and other erroneous concepts) and to oversee its socio-economic and environmental setting.

Water resources cannot be developed without altering the natural environment; thus, one should not define basin yields, either as safe or sustainable, without carefully explaining the assumptions that have been made about the acceptable effects of ground water development on the environment. Even with assumptions about acceptable changes, the concept of a static safe, or sustainable, yield may not be realistic in light of potential changes in hydrology from landuse activities and climate change. For example, urbanization and agricultural development in a basin affect infiltration, runoff, evapotranspiration, and recharge, resulting in the changing of hydrologic cycle through time.

a) Summary Remarks

Although many people have expressed concerns about the ambiguity of the term sustainability, the fact remains that prudent development of a ground water basin in today's world is a complicated undertaking. A key challenge for sustained use of ground water resources is to frame the hydrologic implications of various alternative development strategies in such a way that their long-term implications can be properly evaluated. Each hydrologic system and development situation is unique and requires an analysis adjusted to the nature of the water issues being faced, including the social, economic, and legal constraints that must be taken into account. The role of hydrologists in addressing issues of sustainability is evolving as technologies, understanding of the long-term effects of ground water consumption, and societal priorities. For example, meeting the challenges of water resources sustainability increasingly involves understanding and predicting long-term ecological and water quality impacts and applying innovative approaches to conjunctive use of ground water and surface water, artificial recharge, and water reuse. Scientists and engineers should continue to play a key role in shaping this transition.

References Références Referencias

1. Alley, W.M., R. Healy, J..La Baugh, and T. Reilly. 2002. Flow and storage in groundwater systems. Science 296, 19851990.
2. Alley, W.M., T. Reilly, and O. Franke. 1999. Sustainability of groundwater resources. US. Geological Survey Circular 186.
3. Banks, H. 1953. Utilization of underground storage reservoirs. Transactions, American Society of Civil Engineers 118, 220234.
4. Bredehoeft, J. 1997, Safe yield and the water budget myth. Ground Water 35, no. :929.
5. Bredehoeft, J.. 2002. The water budget myth revisited: Why hydro geologists model. Groundwater 40, no. 4: 340345.
6. Bredehoeft, J.., S. Papadopulos, and H. Cooper. 1982. The water budget myth. In Scientific Basis of Water Resources Management, 5157. Washington, DC.: National Academy Press.
7. Brookshire, D, R. Cummings, and W. Schultze, 1986. Valuing Environmental Goods: An Assessment of the Contingent Valuation Method. Totowa, New Jersey: Rowman & Allanheld.
8. Devlin, J.F.; Sophocleous, M. 2005. The persistence of the water budget myth and its relationship to sustainability. Hydrogeol. J. 13, 549-554.
9. Downing, R. 1993. Groundwater resources, their development and management in the UK: An historical perspective. Quarterly Journal of Engineering Geology 26, 335358.
10. Gleick, P. 2001. Safeguarding our water: Making every drop count. Scientific American 284, 2833.
11. Hiscock, K., M. Rivett, and R. Davison (eds.. 2002. Sustainable groundwater development. Special Publication No. 193. London: Geological Society.
12. Kalf, F.R.P.; Woolley, D.R. 2005. Applicability and methodology of determining sustainable yield in groundwater systems. Hydrogeol. J. 2005, 13, 295-312.
13. Kazmann, R. 1956. Safe yield in groundwater development, reality or illusion? Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 82, no. IR3: 12.

14. Lee, C.. 1915. The determination of safe yield of underground reservoirs of the closed basin type. Transactions, American Society of Civil Engineers 78, 148251.
15. Loucks, D. 2000. Sustainable water resources management. Water International 25, no. 1: 310.
16. Meinzer, O. 1923. Outline of groundwater hydrology with definitions. US. Geological Survey Water Supply Paper 494.
17. National Research Council. 1999. Our Common Journey: A Transition Toward Sustainability, Washington, DC.: National Academy Press.
18. Norton, B., and M. Toman. 1995. Sustainability: Ecological and economic perspectives. Resources for the Future Discussion Paper 9534.
19. Prudic, D., and M. Herman. 1996. Groundwater flow and simulated effects of development in Paradise Valley, a basin tributary to the Humboldt River in Humboldt County, Nevada. US. Geological Survey Professional Paper 1409.
20. Sophocleous, M. 1997, Managing water resources systems: Why safe yieldis not sustainable. Groundwater 35, no. 4: 561.
21. Sophocleous, M. 2007. Science and practice of environmental flows and the role of hydrogeologists. Groundwater 45, 393-401.
22. Sophocleous, M. (ed.). 1998. Perspectives on sustainable development of water resources in Kansas. Kansas Geological Survey Bulletin 239.
23. Sophocleous, M. 2000. From safe yield to sustainable development of water resources: The Kansas experience. Journal of Hydrology 235, 2743.
24. Stewart, S. 2003. Written communication via e-mail to Stanley A. Leake, January 31, University of Arizona.
25. Sophocleous, M. 2005. Groundwater recharge and sustainability in the high plains aquifer in Kansa, USA. Hydrogeol. J. 13, 351-365.
26. Sophocleus, M.; Devlin, J.F. 2004. Discussion on the paper —The water budget myth revisited: why hydro geologists model‖ by John Bredehoeft. Ground Water 42, 618·
27. Theis, C. 1940. The source of water derived from wells: Essential factors controlling the response of an aquifer to development. Civil Engineer 10, 277280.
28. Thomas, H. 1951. The Conservation of Ground Water. New York; Mc Graw Hill.
29. Todd, D. 1959. Groundwater Hydrology, New York: Johnwiley.
30. UNESCO Working Group M.IV, 1999, Sustainability Criteria for Water Resource Systems. Cambridge, U.: Cambridge University Press. World Commission on Environment and Development. 1987.Our Common Future. New York: Oxford University Press,
31. Yihdego, Y. and Webb, J.A., 2011. Modeling of bore hydrograph to determine the impact of climate and land use change in a temperate subhumid region of south-eastern Australia. Hydrogeology Journal, Volume 19, Issue 4, 2011, page 877-887. http://link.springer.com/article/10.1007/s10040-011-0726-1
32. Yihdego, Y and Becht, R., 2013. Simulation of lake–aquifer interaction at Lake Naivasha, Kenya using a three-dimensional flow model with the high conductivity technique and a DEM with bathymetry. Journal of Hydrology, 503:111-122. http://dx.doi.org/10.1016/j.jhydrol.2013.08.034
33. Yihdego, Y, Webb, J.A. and Leahy P., 2016a. Modelling of water and salt balances in a deep, groundwater-throughflow lake- Lake Purrumbete southeastern Australia. Hydrological Sciences Journal. 6(1): 186-199. http:// dx. doi. org/10. 1080/02626667.2014.975132
34. Yihdego, Y, Reta, G and Becht, R., 2016b. Hydrological analysis as a technical tool to support strategic and economic development: case of Lake Navaisha, Kenya. Water and Environment Journal 30(Issue 1-2):40-48.DOI:10.1111/wej. 12162 http://onlinelibrary.wiley.com/doi/10. 1111/wej.12162/full
35. Yihdego, Y and Drury L., 2016a. Mine dewatering and impact assessment: Case of Gulf region. Environmental Monitoring and Assessment Journal 188: 634. doi:10.1007/s10661-016-5542-6. http://link.springer.com/article/10.1007/s10661-016-55426
36. Yihdego, Y., 2017. Engineering and enviro-management value of radius of influence estimate from mining excavation. Journal of Applied Water Engineering and Research.DOI:10.1080/ 23249676. 2017.1287022. http://dx.doi.org/10. 1080/23249676. 2017.1287022. http://www. Tandfonlinecom/doi/full/10.1080/23249676. 2017.1287022
37. Yihdego, Y., and Paffard A., 2016. Hydro-engineering solution for a sustainable groundwater management at a cross border region: case of Lake Nyasa/Malawi basin, Tanzania. International Journal of Geo-Engineering 7: 23. DOI: 10.1186/s40703-016-0037-4. http://link.springer.com/article/10.1186/s40703-016-0037-4
38. Yihdego, Y., Webb, J.A., Vaheddoost, B. 2017. Highlighting the Role of Groundwater in Lake–Aquifer Interaction to Reduce Vulnerability and Enhance Resilience to Climate Change. Journal of Hydrology, 4(1), 10. DOI: 10. 3390/ hydrology 4010010. http:// www.mdpi. com/2306-5338/4/1/10
39. Yihdego, Y and Drury L., 2016b. Mine water supply assessment and evaluation of the system response to the designed demand in a desert region, central Saudi Arabia. Environmental Monitoring and Assessment Journal 188: 619. doi: 10.1007/s10661-016-5540-8. http:// link. springer. com/ article/ 10. 1007% 2 Fs 10661-016-5540-8
40. Kendy, E. 2003. The false promise of sustainable pumping rates. Groundwater 41, no. 1: 2.