Expanded Vision: The Global Water Crisis and the Importance of The Groundwater Project

John Cherry, on behalf of The Groundwater Project
Guelph, ON, Canada, November 1, 2023

SYNOPSIS

Many important global organizations have concluded that there is a global freshwater crisis. In the past two years both the UN and UNESCO have convened major conferences on the crisis. The freshwater crisis is exacerbated by global warming, yet, in the short term, water scarcity with impacts on food and poverty are the most immediate threat to civilization. This document describes the freshwater crisis from a groundwater perspective and presents The Groundwater Project as an important and unique philanthropic innovation towards reversing the water trajectory.

Groundwater is at the heart of the freshwater crisis. A key factor in the evolution of this crisis – and the lack of substantial effort to reverse its disastrous trajectory – is the minimal awareness and understanding of groundwater beyond the groundwater science community (i.e., professional hydrogeologists) and the scarcity of human expertise and organizational capabilities to analyze and solve groundwater problems. Our motivation is to address these related issues through education and, where possible, technical assistance, especially in the developing world.

To enhance prospects for the needed expansion of human capacity in groundwater problem solving and public understanding of 'all things groundwater', the Groundwater Project (www.gw-project.org) was initiated in 2017. The Groundwater Project is a volunteer-based, charitable nonprofit organization (NGO) registered in Canada and global in scope. It is committed to the advancement of groundwater understanding and awareness by creating and making high-quality groundwater learning materials in many languages available for download free of charge from its website (gw-project.org). The Groundwater Project's mission – *making groundwater understandable* – is based on the philosophy that groundwater knowledge should be free and should be used to manage the water crisis. The Groundwater Project has greatly expanded its initial vision as an act of hope in a troubled world.

THE GLOBAL WATER CRISIS WITH GROUNDWATER AT ITS CORE

Climate, wars, pandemics, and recessions threaten our society's future, but the most immediate threat is availability of fresh water. To summarize the current situation, the following events are listed in chronological order:

- In 2008, the UN Intergovernmental Panel on Climate Change concluded that "water and its availability and quantity will be the main pressures on, and issues for societies and the environment under climate change" (Bates et al., IPCC Secretariat).
- Lester R. Brown (2013), the author of *Full Planet, Empty Plates*, stated, "The real threat to our future is peak water."
- According to The National Intelligence Council (USA, 2014), "The world is entering a prolonged water crisis."

Groundwater is Key to 8 of the 17 UN Sustainability Goals

The Global Water Crisis is a Groundwater Crisis because groundwater makes up 99% of all liquid freshwater & at time of drought groundwater is the only freshwater available in many regions

- In 2015, the World Bank declared: "Water is reaching a tipping point." Five years later in 2020, UNESCO stated: "Groundwater is key to 8 of the 17 United Nations Sustainability Goals."
- The US National Intelligence Council's Strategic Futures Group (2021) said "Water insecurity is threatening global economic growth, political stability."
- Also in 2021, the World Economic Forum noted "Water insecurity risks triggering a global food crisis."
- The United Nations designated 2022 as The Year of Groundwater and held two water conferences: the UNESCO Groundwater Summit in Paris in December 2022 focused on groundwater but without a groundwater science framework; and the UN Water Conference in New York City in March of 2023. In the opening address in New York, King Willem-Alexander of the Netherlands stated, "by 2030, half of humanity will be living in extreme water stress." However, the groundwater science component of the UN Water Conference (2023) was minimal with no coverage of the specific challenges and proposed solutions.

A Groundwater Project aim is to elucidate challenges related to groundwater issues, identify the most effective policy innovations, and propose technical solutions from the groundwater perspective.

The global water crisis is in fact a groundwater crisis because groundwater makes up 99% of all liquid fresh water and at times of drought, groundwater is the only freshwater available in many regions. This makes a huge difference in both understanding the water crisis and charting

a path for avoiding disaster. Reliance on groundwater is growing while availability is diminishing. Those who will bear most of the negative consequences do not realize what is happening. For our civilization to continue, there must be sufficient freshwater, productive soil, and oceans, as well as a habitable climate. Of these, the most complicated, complex, least understood, and least monitored is groundwater on which nearly all freshwater systems rely.

The Water Crisis is a Perfect Storm

It is little recognized that the freshwater crisis is a perfect storm coming from four groundwater-dependent directions:

1) **Water poverty** in regions where there are too few wells and too little pumping from existing aquifers (i.e., sub-Saharan Africa); people living here drink unsafe water, mostly unknowingly, or walk too far for their water.
2) **Aquifer depletion** in regions where there is too much groundwater mining (i.e., USA High Plains, Middle East, and North Africa); few of the people relying on this water realize that their essential water is disappearing.
3) **Groundwater contamination**, widespread and growing with an ever-increasing diversity of chemicals including pesticides, pharmaceuticals, PFAS, known as the forever chemicals, and pathogens; those impacted do not realize that groundwater is the cause.
4) **Ecological damage** with diversity loss due to the drying of wetlands as water tables drop due to excessive pumping, and contamination spreads with minimal monitoring and understanding.

The many groundwater problems in each of these four categories in total threaten global civilization to the same extent as climate change but on a much shorter time fuse. If water causes societal collapse, there will be no societal determination or economic capability for continuing the task of reducing greenhouse gases.

WATER POVERTY

In many regions of large-scale agriculture, groundwater needs to be pumped less but this is not so for many other regions where there is rural water poverty. People in these regions cannot escape this suffering unless many more safe wells are drilled. These wells need to be mostly low-cost small-diameter wells with sufficient yield ("small wells") for self-reliant (family) farming. Wells need to be constructed with a sanitary seal (e.g., clay, cement grout) to prevent contamination entering the aquifer along the outside of the well casing. In many countries this is not standard practice (i.e., not regulated). These drilled small-diameter wells accommodate the pumps capable of raising water from the depths needed to eradicate water poverty.

Small wells for this purpose would dramatically improve outcomes with minimal chance of draining aquifers. This need encompasses 3 billion rural people for whom more than tens of millions of low-cost safe wells are needed, many should be used in combination with rainwater harvesting, point-of-use filters and appropriate sustainable water and soil family farming. Water scarcity in small agriculture involves more than 1.5 billion people on family farms with another 2 billion living with other extreme water stresses. Nearly two-thirds of humanity is currently or soon will be suffering from water problems of one kind or another with most problems worsening. In 2014, Peter Gleick wrote "*The failure to provide safe drinking and adequate sanitation water to all people is perhaps the greatest development failure of the twentieth century.*"

The United Nations estimated in 1975, when the global population was only 4 billion, that 1.2 billion people were living in water poverty. In 2010 the UN passed its resolution that access to adequate safe water is a human right, however, those without this right have increased. The UN issued the Sustainability Goals in 2015 to be achieved in 2030. Eight of these goals are dependent on groundwater and none are on track to be met by 2030. Overall, the situation is worsening even though many billions of dollars have been spent aimed at reducing this form of human suffering; these efforts are well-meaning but largely ineffective for reducing the numbers. However, much has been learned, mostly by small NGOs, about what does and does not work; the challenge now is to capitalize on this learning and emphasize innovation. UNESCO (March 22, 2022) reported, "*The further development of groundwater in Sub-Saharan Africa where water poverty is widespread is not currently limited by a lack of natural groundwater resources... the general lack of groundwater professionals impacts the staffing of institutions and of local and national government offices in many countries, hampering emerging initiatives to oversee effective groundwater monitoring and development.*" The Groundwater Project is aimed at being a key part of the solution.

Water Poverty ⟺ Aquifer Depletion

- Affects 3 billion people.
- Requires tens of millions of low- cost safe water wells.
- Two-thirds of population faces water stress.

- Irrigation accounts for 70% of global freshwater withdrawals.
- Aquifers are being drained and many are on the brink of collapse.

AQUIFER DEPLETION

In other parts of the world groundwater is being relied on too much for food production using large scale irrigated agriculture. In these regions aquifers are being drained and many are on the brink of collapse. These regions typically have minimal groundwater monitoring and management that enables the over-exploitation to proceed underreported. Irrigation accounts for 70% of global freshwater withdrawals and produces 40% of global food which leaves our global food supply chains at risk of collapse. The global food system has become fragile due to many influencing factors but running out of water during drought when the aquifers have already been depleted is the one factor beyond repair. Competition for water is increasing, including competition between the urban centers and farmers. One third of the largest aquifers are considered for practical purposes to be stressed beyond recovery while many others are on an unsustainable path. In some regions, extreme food insecurity tied to soil loss from salinization due to irrigation and erosion has triggered migration, social instability, and armed conflicts. In his book Running Out: In Search of Water on the High Plains, Lucas Bessire concludes: "*The imminent depletion of the Ogallala aquifer and other aquifers around the world is a defining planetary crisis of our times."* This aquifer supports around one-sixth of the world's annual grain produce.

The total sustainable groundwater use for all purposes has reached or has passed its global peak, meaning that no additional water is available in many regions and many aquifers are at or beyond their tipping point and therefore the amount of available groundwater must decline sooner or later. Most importantly, this situation exists while water demand and population continually rise and while groundwater contamination spreads largely unrecognized. Corrective policy responses on the scale at least of those in motion to reduce anthropogenic greenhouse gas emissions are essential to reverse the water depletion trajectory.

We have seen the leading edge of an increasing trend towards more frequent and longer droughts. Diminished groundwater resources means that during periods of long drought, there will be no water left to support communities. This is a crisis in that groundwater supplies half the global population with drinking water, including half of the world's megacities, the largest being Mexico City, Djakarta, Lagos and São Paulo.

Aquifer depletion is so extreme that water mined from the continents to eventually escapes to the oceans as wastewater accounts for about 25% of global sea level rise. Furthermore, land subsidence triggered by excessive groundwater withdrawals along coasts is causing the seas to flood coastal megacities where nearly half a billion people live. This is a manageable aspect of climate-related sea level rise that should be addressed. One aim of the Groundwater Project is to issue books that report rigorously on each of these disparate pieces of the depletion problem and provide guidance on how to reverse the depletion trajectory.

GROUNDWATER CONTAMINATION

According to the World Bank (2023), "*ever increasing detections of anthropogenic pollutants, including chemicals barely recognized as contaminants a few years ago, pose problems on a scale that is often not appreciated*". The diverse activities of humans result in millions of different chemicals released onto and into the ground from industrial, agricultural, and municipal activities but only a small percent is made up of chemicals mobile enough to damage groundwater. However, some of these chemicals are long lasting (do not degrade) and add up to thousands of individual chemical compounds in some aquifers. Typically, when judged according to their very low individual concentrations, there is little reason for concern, but when the diverse chemical types are considered in combination, the health and ecological effects are unknown. In addition to this threat to human health and ecological systems, there is the widespread and increasing occurrence of nitrate (NO_3) in groundwater, mostly from agriculture, for which recent studies indicate greater human health and ecological risks than previously thought.

There are three reasons why groundwater contamination is a much greater long-term risk to humans and ecosystems than contamination of rivers and lakes. First, groundwater contaminants accumulate in aquifers and are not, as in rivers and lakes, flushed out or buried in the bottom mud over a few years or decades. Second, contaminated water pumped from aquifers typically shows no evidence of the contamination to the human senses, so that the water seems pristine. Third, indication of contamination effects can be obtained from living creatures in surface waters from biological indicators but not for water from wells. The human receptors are the indicator species, but they are rarely studied as such. Of the four directions of the perfect storm, groundwater contamination is the least monitored, least understood, and least researched. The Groundwater Project has books and lectures in preparation on this topic.

Ecological Damage

Extraction of water from aquifers unavoidably causes the water table to drop near the wells. Extracted water is part of the rainfall in the hydrological cycle which recharges the aquifer and is then pumped by the well, but which formerly sustained groundwater dependent ecosystems. If the extraction from the aquifers causes excessive depletion that drops the water table too much, wetlands, streams, rivers and lakes and springs receive too little of the rainfall and become water starved from the perspective of groundwater dependent ecological systems. This is a particularly deceptive form of environmental damage that contributes to diversity loss but generally escapes notice because direct evidence of the water table decline due to aquifer depletion requires monitoring of the types only rarely done. This means that by the time the link to groundwater is figured out, it is generally too late for corrections to restore ecological health.

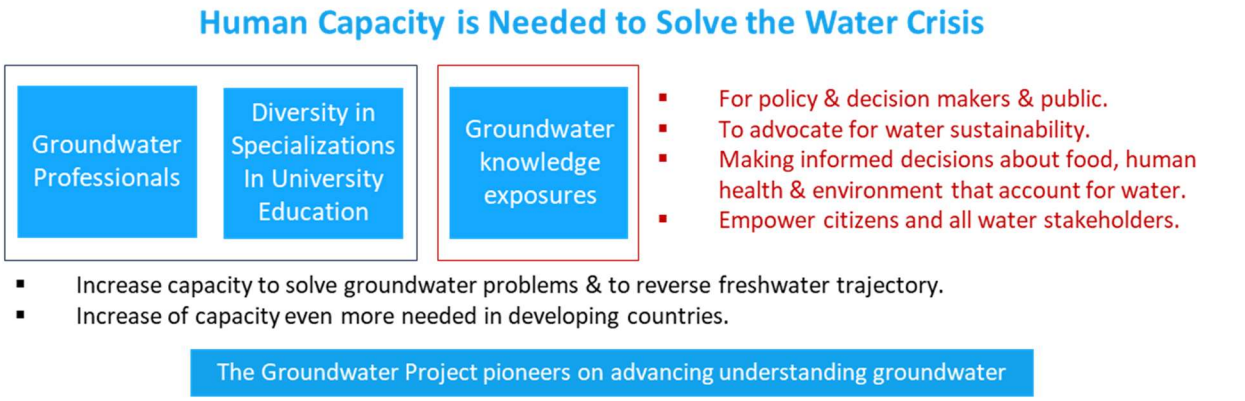
Too much groundwater extraction in groundwater dependent ecosystems cause depletion of streams and wetlands impacting aquatic habitats

Groundwater seepage sustains many water holes essential for life

Human Capacity is the Key Limitation to Progress

The water crisis has unprecedented complications and complexity. There is a woeful deficiency in human capacity for solving groundwater problems and this is the main impediment to reversing the freshwater trajectory. Lack of human capacity includes both the small number of groundwater professionals and lack of diversity in specializations in university education of groundwater professionals in the highly industrialized countries and even more so in the developing countries.

Policy and decision makers, as well as the public, have been given insufficient exposure to groundwater knowledge to advocate for water sustainability and for making informed decisions about food, human health, and the environment that account for water. Enhanced public understanding is essential to empower citizens and all water stakeholders to take informed local actions. The Groundwater Project pioneers on advancing understanding groundwater.



Hazardous Groundwater Quality from Natural Causes

The freshwater perfect storm coming from four directions is superimposed on the lingering cause of human health impacts that results from harmful natural constituents in groundwater in many regions. These constituents that are geogenic rather than anthropogenic originate in the geologic materials (minerals and rocks) but their release can be promoted by where and how the groundwater is exploited. These geogenic constituents have been causing adverse health effects for as long as groundwater has been in use but have been amplified many times over by modern drilling that makes deeper wells and wells in hard rock. According to the World Bank (2023), since the 1980s natural health-threatening contamination from arsenic, fluoride, manganese and uranium is more extensive and more serious than previously thought. Arsenic affects the most people but was given little attention until the 1990s but is now known to have affected more than 150 million people, mostly in Bangladesh, Pakistan, and China but also in parts of the United States, Mexico, and Canada. It is estimated that 150 million people are at health risk from fluoride (fluorosis).

The Unique Institutional Challenge of the Groundwater Quality Problem

When taken together, the adverse effects on human health of harmful geogenic and anthropogenic constituents in well water are potentially immense but uncertain. What the geogenic and anthropogenic problems have in common globally is the long delay by the organizations responsible for water and health in recognizing the problem as an issue worthy of action. What sets these groundwater issues apart from the many other water and health issues is that, for a government agency to conduct the appropriate type of private- and small-community well sampling for quality takes organization courage. If the results show that substantial numbers of wells have harmful constituents, the well owners will want to know for how long the well water has been potentially harmful and has there been real harm. There can be no reliable answers to this question but typically and reasonably so, there will be people in the community who blame illness that they know of on the well water and will demand explanation for why it took so long to carry out the well sampling. If there were to be organizational courage, it is unlikely for there to be the political courage to allow the organization to potentially trigger a crisis of public fear and blame. The World Bank (2023) advises concerning groundwater quality that, “many of the problems described are a result of systematic institutional failures and reform of these institutions and their professional culture will be required to resolve them”. The Groundwater Project has books in

preparation aimed at private at the education of well owners, water managers and public health agencies about these matters.

THE GROUNDWATER PROJECT

Towards expansion of human capacity in groundwater problem solving and public understanding of '**all-things-groundwater**', the Groundwater Project (www.gw-project.org), a Canadian-based charitable NGO of global scope, was initiated in 2017. The Groundwater Project is committed to the advancement of groundwater understanding and awareness by creating and providing high-quality learning materials in many languages for downloading from the internet, with the unique feature that our products, all rigorously peer reviewed, are **free-of-charge**. It is aimed at creating hundreds of **books**, **lectures**, and **multimedia videos**. Its goal is the conversion of this groundwater knowledge into learning for the underpinning of sustainable practices. Foundational to the Groundwater Project's philanthropic work is a growing list of more than a thousand volunteers, with exceptional expertise that includes scientists and practitioners from more than 70 countries. The Groundwater Project publishes books in many categories for readerships of all levels in diverse global circumstances, to serve humanity and ecosystems. With a readership in 174 countries globally, the Groundwater Project is the only organization in the world devoted to synthesis of groundwater science for creation of free usable knowledge, easily accessible in many languages with translations by volunteer experts in the subject matter. The Groundwater Project is essential to creating the human capacity to build awareness and understanding about groundwater and the human capacity to assess problems and design solutions concerning groundwater issues that relate to food, poverty, energy, biodiversity, and climate resilience.

SYNTHESIS IS THE PROCESS THAT CONVERTS SCIENTIFIC ADVANCES INTO ACTIONABLE KNOWLEDGE

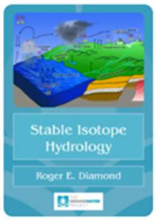
Synthesis is at the heart of the Groundwater Project. Groundwater is a field with many specialized sub-fields. Books must be written by authors with deep knowledge for the information to be both accurate and accessible. Deep knowledge and understanding comes from synthesis by which hundreds or thousands of papers scattered in the literature on each topic are reviewed by experts who convert the knowledge into books. Those who synthesize research must have exceptional understanding of the subject by extensive work experience and/or research. For synthesized knowledge to be made understandable for the greater good, it must be written up in different versions, understandable by those in the different readership categories. These include young children, junior school students, high school students, undergraduate and graduate college students, professors, the public, and water and environmental professionals educated in disciplines other than groundwater. In addition, books are needed to provide specialized synthesized knowledge for groundwater professionals. Books for high school students must be less demanding than books for university students but the simplification must avoid inadvertent misleading or incorrect representations. Synthesis is much more challenging than the writing of niche papers for scientific journals and this is why synthesized groundwater books by commercial publishers are rare.

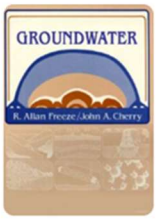
The Groundwater Project

Mission | Making Groundwater Understandable.

Vision | Build the human capacity for sustainable development and management of groundwater.

Philosophy | Groundwater knowledge should be free and should be used to manage the water crisis.





Synthesis of Scientific Publications

Actionable Knowledge

OBJECTIVES

1

Books

Original Books

Preservation of Legacy Books

Translations

Groundwater Topics & Sub-Specialties

Interface Groundwater & Other Disciplines

Different Categories of Readerships

Understandable Books – Accurate & Aaccessible

- ✓ Pre & grade school students
- ✓ Under & graduate students
- ✓ Professionals / continuing education
- ✓ General public

Based on the books

2

Interactive Learning Materials (modules, videos)

Identifying the Essential Knowledge Components for Various Educational Curricula

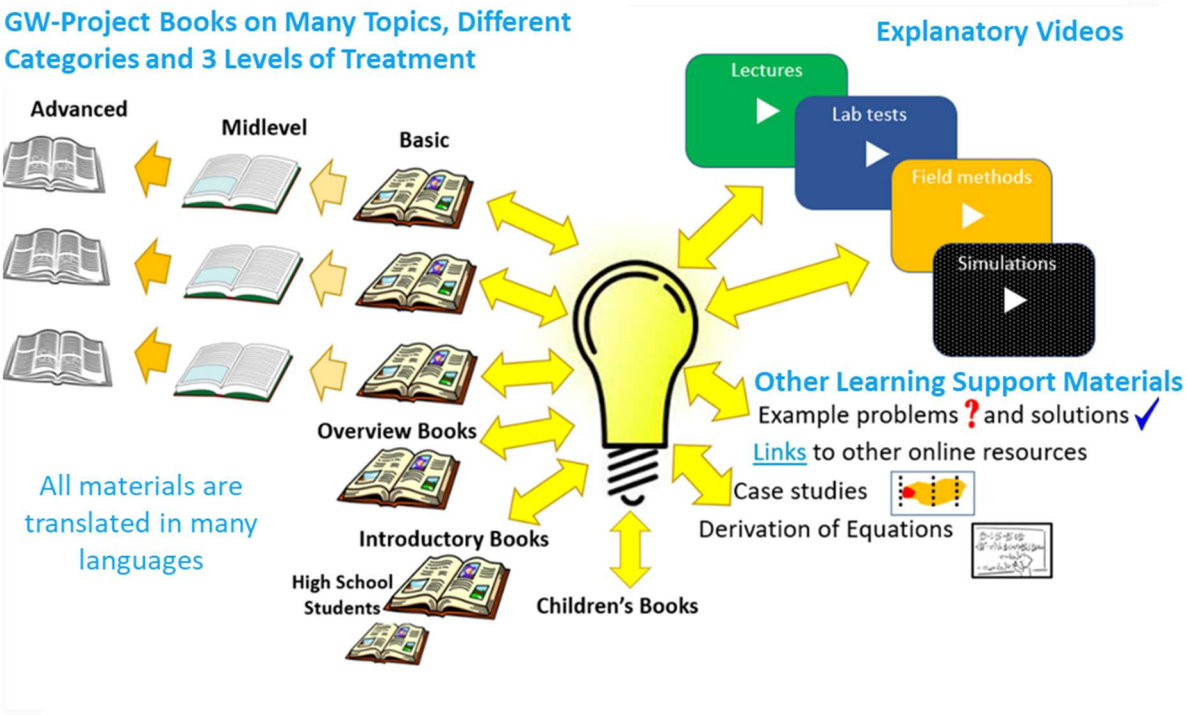
3

Books

Reporting on the State of the Planet from a Groundwater Perspective

Focus on:

- ✓ Aquifer Depletion
- ✓ Water Poverty
- ✓ Groundwater Pollution
- ✓ Groundwater dependent ecosystems
- ✓ Food insecurity
- ✓ Groundwater Footprint

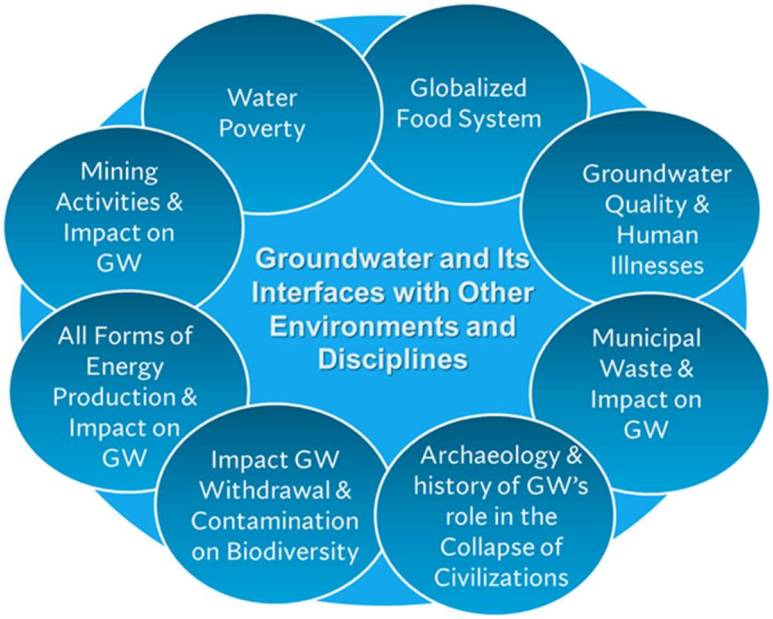


GROUNDWATER AND ITS INTERFACES WITH OTHER ENVIRONMENTS AND DISCIPLINES

Many of the harmful groundwater side effects of human practices are not being recognized as such. An aim of the Groundwater Project is to make them widely known and demonstrate how groundwater serves humanity by enabling our modern, unsustainable society to function as we consume and degrade groundwater. This must be understood as a basis for the corrections needed aimed at sustainability. An important question is: how can we better anticipate damaging effects and apply the *Precautionary Principle* during increasing demand on groundwater and climate change?

To cover the groundwater knowledge most important to society, hundreds of books are required because there are so many different manifestations of groundwater and its problems depending on the combinations of geology, topography, climate, and stage of industrialization. Also, the policy framers and decision makers who are determining humanity and the planet's fate need to know about the roles and importance of groundwater related to the many ways in which it is impacted by or supports human well-being such as food, poverty reduction, energy, forests, wetlands and ecological systems, which are the interfaces of groundwater with what matters.

Initially, the Groundwater Project was focused on the traditional scope of groundwater science. Now, to make groundwater relevant and understood beyond the groundwater community (i.e., professional hydrogeologists), there are many books at the interfaces, for example:



- The globalized food system, which has become groundwater dependent in ways that promote extreme political instability as water for irrigation declines and soil disappears.
- The many forms of water poverty, where too little water or too much contamination are the primary causes of human suffering.
- Groundwater quality, which causes human illness due to fecal contamination but also due to natural chemicals such as arsenic and the growing combinations of industrial chemicals.
- Mining activities, all of which have groundwater impacts during mining and, most importantly, for centuries after the mines close. What does 'responsible mining' mean?
- All forms of energy production (including solar and wind) have groundwater impacts through water use and contamination during the components manufacturing and operations (e.g., how much groundwater harm is caused by making electric vehicles?).
- Municipal waste, where huge quantities end up in landfills and nearly all landfills leak, now or eventually, to cause groundwater pollution,
- The implications of peak water and decline from the peak, including groundwater linkages and expected impacts on so many aspects of human well-being and societal stability.
- Biodiversity, which is declining due to the drying of wetlands, ponds and rivers from excessive groundwater withdrawal and contamination; most wetlands, streams, and rivers would be dry much of the year without groundwater sustenance.
- Archaeology and history of groundwater's role in the collapse of various civilizations.

Groundwater Project Objectives in its Expanded Vision

The three objectives in the expanded vision for the GW-Project:

1) Creating Books and Related Learning Materials:

This is the initial Groundwater Project objective and is a continuing thrust. That is, to create free, downloadable peer-reviewed books across a wide scope with an expanded effort to include

materials for developing countries and indigenous communities with increased emphasis on interactive learning materials for all interests. This includes case study and field methods books aimed at transferring experience of the older generation to younger generations. It also includes books for stakeholders such as private well owners and well drillers in developed and developing countries, especially where there is rural water poverty, and books for public health organizations that nearly everywhere need to better understand the nature and risks of private wells, small community wells, and sampling protocols. All books are intensely peer reviewed. Progress to date:

- 40 original books published, 34 near publication, 150 underway, more being identified.
- high credibility: leading experts from >30 countries, > 50% of the books completed include authors with professional awards or honors.
- 12 preserved 'classic' books of enduring value, mostly greater than two decades old,
- 45 book translations completed, some books into 15 languages, 137 translations including in total 47 languages.
- >1000 volunteers: from 70 countries, 283 authors, 406 translators, 287 reviewers, >50 other volunteers including advisors and facilitators.
- >170,000 pdf book downloads in 174 countries and >300,000 web book reads.
- Many small donors, including 31 corporate, 3 universities, and more than 250 individual donations.

2) Identifying the Essential Knowledge Components for Various Educational Curricula:

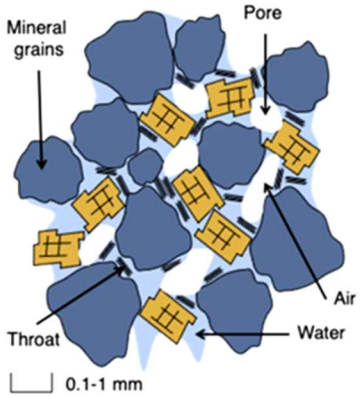
The aim is to embed groundwater science appropriately in education at all levels. Of the immense knowledge in the Groundwater Project books repository, we need to identify and increase the accessibility of the essential elements as building blocks for a variety of curricula including professional education at the master's level in universities, high school, and elementary school levels, and, importantly, continuing professional education. The facts, concepts, processes, and software that are essential for each educational category need to be identified, located amongst the Groundwater Project books, and then arranged for accessibility.

The Groundwater Project aims at enhancing spatial thinking and conceptualizing

- ✓ through 2-D & 3-D visualizations – high quality original illustrations in books.
- ✓ conceptual models.
- ✓ experiential learning through interactive computer simulations.
- ✓ all integrated in short self learning multimedia interactive modules

⇩

To convert book knowledge into actionable learning



3) Reporting on the State of the Planet from a Groundwater Perspective:

The Groundwater Project is expanding into books about the state of the planet from a groundwater perspective to include depletion, food, poverty, contamination, and groundwater dependent ecosystems. These books, along with related video lectures and interactive learning tools, are aimed at the widest possible readership including politicians, water managers and policy makers, public interest environmental groups, research organizations and water poverty. Plans to achieve the desired reductions of anthropogenic greenhouse gases are available such as *Drawdown, The Most Comprehensive Plan Ever to Reverse Global Warming,* (Paul Hawken, Editor, 2017). However, there is no such book for the water crisis. The Groundwater Project will prepare such a book as a proposal for reversing the freshwater trajectory towards disaster. This is necessary because, with drought, groundwater is commonly the only water available and hence is fundamental to solutions and because other organizations lack the critical mass of groundwater and related expertise for this task with a global perspective.

SUMMARY AND REQUIRED FINANCIAL SUPPORT

The global water crisis is essentially a groundwater quantity crisis that impacts food and poverty along with a water quality crisis around human health and ecological systems. It involves two thirds of humanity, now or soon to be in some form of water suffering, worsening with population growth and climate change. Escape from poverty is not possible without safe and accessible water. Water suffering will continue to cause conflict and societal instability, especially as the global population grows by more than a billion people to reach peak population. Impacts from the water crisis are expected to reach critical thresholds sooner than those from greenhouse gas emissions, however this has received little attention. Policy makers need to allocate appropriate attention and funding for water to reverse the current disastrous freshwater trajectory.

In a world where hundreds of millions of wells serve basic needs of drinking water, food production, and industry, it is a near universal experience that top-down management of groundwater does not work because most wells are privately owned, which conveys a sense of water ownership. Groundwater management demands the active participation of the various stakeholders and takes patience, persistence and good will to build a consensus for collective action (World Bank, 2022). For this, better understanding of groundwater by all stakeholders is essential, which is the overarching aim of the Groundwater Project.

With the three objectives (expanded vision), The Groundwater Project's goals are to alleviate the two most critical capacity limitations,1) lack of appropriately educated groundwater and other professionals in developed and developing countries to address groundwater and related problems, and 2) lack of a sufficiently informed public and stakeholders to champion what is needed to take informed local decisions (and influence policy).

Financial support for the Groundwater Project comes mostly from within the groundwater community, nearly all in small donations, however, now much more financial and volunteer support is urgently needed, especially from beyond this community. The Groundwater Project needs consistent annual financial support to plan and manage this ever-expanding global philanthropic volunteer-based enterprise. Specific financial support is needed to:

- Expand capacity (staff, freelance contractors) to increase annual book production (currently we have a growing backlog).

- Expand capacity to engage in working partnerships (e.g., with like-minded NGOs in North America, Europe, South America, Africa, Australia, and Asia, and collaborations with educational institutions on innovative methods adapted to local / regional context).
- Expand must needed support on spatial thinking and conceptualizing for books (creative content creators, assistance with simulations and other content clarifying animations).
- Design and assess experiential learning materials which require support from freelance experts on the subject matter of creating effective learning modules, and support with short video production.
- Engage at important conferences and workshops for the purpose of active participation and expanding the Groundwater Project reach.
- To organize field demonstrations and develop strategies for the needs of developing countries and indigenous people (e.g., workshops on the small wells concept with rainwater harvesting and effective water/soil use in family farming)

The Groundwater Project operates virtually, directed by a management team and Board with advisory teams with no paid executives. The Board meets virtually monthly. The Groundwater Project pays four full-time staff through the University of Guelph (staff is employed by the University of Guelph with funds raised by the Groundwater Project). Board members and staff (project manager) are in communication on almost a daily basis via e-mail and/or virtually. Freelance staff are contracted by the Groundwater Project for formatting, copy-editing, graphic design, and computer simulations. This model allows for efficient and effective use of funds.

About John Cherry and the Groundwater Project Board of Directors

John Cherry, leader of the Groundwater Project, is a Canadian hydrogeologist; Fellow, Royal Society of Canada; Foreign Member, US National Academy of Engineering; recipient of the Stockholm Water Prize (2020) and the Lee Kwan Yew Water Prize (Singapore) (2016). *Board of Directors*: John Cherry, Canada (Chair); Shafick Adams, South Africa; Richard Jackson, Canada; Ineke Kalwij, Canada; Renee Martin-Nagle, USA; Everton de Oliveira, Brazil; Marco Petitta, Italy; Eileen Poeter, USA.

Available – List of Groundwater Project Books

An up-to-date list of the books is available: (i) already published and freely available online at http://gw-project.org); (ii) books nearly ready for publishing; (iii) those in preparation; (iv) other books planned; and (v) book translations.

RELEVANT PUBLICATIONS

1. Alley, William, and Alley, R. (2017). High and Dry: Meeting the Challenge of the World's Growing Dependance on Groundwater, Yale University Press, 294 pages.
2. Barth, J. A. C., Geist, J. A., & Cherry, J. A. (2023). Integrate strategies to save biodiversity and groundwater. Nature, Correspondence, January. https://doi.org/10.1038/d41586-023-00216-9.
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4. Cherry, J. A. (2022). The Groundwater Project as knowledge philanthropy. AWRA, 4, 22 24.
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