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Framework and Function of Integrated Water Resources Management in Support of Sustainable Development

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Abstract: Sustainable Development Goal 6 addresses water issues, and Target 6.5.1 sets a goal to implement integrated water resources management (IWRM) at all levels. The reporting system shows slow progress, which indicates that changes are needed. The assessments focus mainly on the function of IWRM as a framework of institutional arrangements and less on its function as a process for water resources management, with emphasis on practices like multi-objective planning and stakeholder participation. While IWRM has a rich body of knowledge and wide recognition among water management communities, it is still misunderstood and criticized by some stakeholders, even after 25 years of explanations. While its support base appears stable, indications of fatigue and waning interest in IWRM point to the need for fresh explanations and demonstrations. These can be facilitated by distinguishing the functionalities of IWRM as a framework and a process. SDG data focuses on its framework function, which generally tracks the status of environmental governance in countries. Case studies provide better indicators of its use as a process, but their narratives may not be persuasive. If educators adopt the framework and function model of IWRM advocated in the paper, the narratives can improve and facilitate greater acceptance. Advancement of IWRM implementation to support the Sustainable Development Goals requires continued support by the Global Water Partnership, which might be bolstered by cooperation with international water associations for standardization, accreditation, and credentialing. IWRM's future implementation will also depend on its adoption among educators and on interdisciplinary approaches.

Keywords: IWRM; case studies; comprehensive water management; partnerships; SDGs

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1. Introduction

Effective stewardship of water resources is a critical global need, as signaled by its recognition as an important factor in the Sustainable Development Goals (SDGs) [1]. Progress has required shifts from single-purpose methods toward integrative approaches because water connects societal and environmental systems, and emphasis must be placed on the involvement of all stakeholders [2]. One such integrative approach, integrated water resources management (IWRM), has gained widespread recognition, which is sustained by its sponsorship by the Global Water Partnership (GWP), the international non-governmental organization that created the concept. While other approaches also use integrative methods, they have less support and lower levels of recognition than IWRM. These are explained later in the context of comparing them to IWRM.

This paper is a review of major trends and thought leadership about integrative methods for water resources management, with a focus on IWRM and its effectiveness. Few people disagree that IWRM is needed, but they are likely to disagree on exactly what it means and how it works [3]. Such disagreements are expected, given the diverse perspectives, experiences, and incentives involved. Although an attempt was made at the initiation of IWRM to clarify its meaning [4], the disagreements about what IWRM means and how it should work have continued for a long time without broad consensus [5].

If more consensus about IWRM could be achieved, the interdisciplinary field of water resources management and its contribution to achieving the SDGs would benefit [6]. No

general framework like IWRM is perfect, but its shortcomings are not due to conceptual deficiencies so much as to communication, which hampers public understanding and leads to uneven support for decisions [7]. The communication problems about water issues stem from their complexity [8], their connections with other sectors [9], and the communication barriers between policymakers, experts, and the lay public [10]. The problems vary among settings due to scale and contextual arrangements, as well as perspectives that vary among disciplines and interest groups.

While dialogue about IWRM can be healthy, it can also sap support for it and have a negative effect on the achievement of the SDGs [11]. Not everyone sees IWRM as entirely positive [12,13]. In the worst case, the ongoing dialogue could lead to a loss of interest in IWRM. To avoid this, the dialogue should converge so that recruiting leaders, explaining solution paths, and fostering cooperation among stakeholders can support the SDGs. These indications point to a need to improve communication about the approach, especially among students, water managers, stakeholders, and the broader public.

The proposition behind this paper is that an important conceptual issue with IWRM is that it serves two functions, and by clarifying them, a clearer picture of it will result. One function is to provide a framework for a collection of institutional arrangements for water management policies, principles, and practices so they can provide support for management actions. This function would seem to apply anywhere in the world and is labeled here as the IWRM framework. The other function, which is labeled here as the IWRM process, is to be used as a sequence of steps toward solutions to a range of different types of water-related problems that depend on conditions at the points of application. Underlying the proposition is the assumption that IWRM was conceptualized to perform both functions, but the framework function has become more prominent. The other part of that theory is that the process functionality requires more clarity and is arguably more complex and variable than the framework function.

This paper includes a review of the emergence and applications of IWRM and how well it has been implemented in its dual roles as a framework and process. The review addresses whether commitment to IWRM as the main organizing concept for comprehensive water resources management is sustainable, whether data on its implementation indicates adequate uptake and progress, and whether the institutional arrangements for it indicate a likelihood of success. Preparing managers, advisors, facilitators, and stakeholders to use IWRM is important, and the water management literature contains many papers about their roles [11]. Much of IWRM's future lies in its adoption among educators and in training programs, and discussion is included about how lessons learned can be used to design improved packages for coursework and training.

The core questions addressed in the paper are about how IWRM has been conceptualized, how the status of its implementation is assessed, how it relates to the SDGs, how implementation can be strengthened, and what the roles and responsibilities should be going forward. The paper is based on a literature review, an analysis of case studies, a review of sources about the implementation and results of IWRM, and the writer's experiences in several facets of water management, including IWRM projects, research, graduate education, and training programs. As a starting point, the paper provides a summary of recent bibliometric studies of themes related to IWRM.

2. Bibliometric Studies Relating to IWRM

To initiate the review, a search was made of bibliometric reviews of IWRM thought leadership. It indicated that the many strands of research related to the IWRM concept require that it be approached piecemeal, with a meta-analysis connecting the pieces. No bibliometric analysis at such a high level was identified, but several reviews of themes within IWRM were located.

Reflecting the more common topic of water resources management, the general picture showed that research interest in it had increased in the last two decades, with emphasis on integration as a subtheme [14,15]. Regarding subthemes, the writer determined in a related

study that many bibliometric analyses had been conducted about flood risk, which is one aspect of integration. The focus on integrated flood risk management as part of IWRM began in about 2005, and a comprehensive overview of the issues was published by the Associated Programme for Flood Management, which includes the participation of the GWP [16]. Some 25 bibliometric reviews of integrated flood management were reviewed and classified into categories. Their themes showed a continuing shift toward nonstructural strategies [17] and a large increase in publications during the last two decades. As with IWRM, many topics were addressed, indicating the complexity of the subject matter [18].

In the reviews for this paper, integration of disciplines, sectors, and interest groups was perceived as essential. The social science focus on integration was mainly through economics, with less attention from law, policy, and stakeholder participation. It was evident that interdisciplinary science required more attention, especially in the non-economic social sciences [19].

Nexus themes were prevalent in the review, and SDG studies showed that they, along with concepts such as water security and ecosystem approaches, are still in an early stage. Connections between research findings and SDG 6 issues were perceived as often not clear, including Target 6.5 [20]. The nexus research pointed toward research on connecting sectors, with growth in attention to the water–energy–food nexus (WEFN), but indicated challenges in moving from nexus thinking to action [21]. One review showed some 10,208 articles from 2012 to 2022, with emphasis on the WEFN and its intersectoral interactions and regional issues [22].

The emphasis on water governance research has been mostly in developed countries, with indications that adaptive approaches will be crucial for sustainable urban development [23]. Stakeholder participation is, of course, a critical topic within IWRM, and studies on how citizen science with participatory perspectives can be used are increasing [24]. Studies also indicated that communication and integration within disciplines would be future research directions, indicating that further work is needed on them [25].

To summarize, bibliometric studies relating to IWRM tend to focus on its themes as opposed to the general concept. Further reviews of related research will now be presented for how IWRM evolved, how it is conceptualized, how results are measured, and roles in education and training.

3. IWRM and the Global Water Partnership

A central issue in the acceptance of IWRM is whether it only applies in the context of developing countries or whether it applies everywhere. The concept was created primarily as a tool to respond to needs in developing countries, and time may have warped understanding about this [26]. The original focus on developing countries has been sustained in large part by the Global Water Partnership (GWP), which is a donor-supported nongovernmental organization. The case studies posted by the GWP show how IWRM is still primarily a tool for developing countries. It should be applicable in other settings because it uses accepted methods and tools for planning, analysis, and management, but there is less interest in it in these other settings. Some practitioners in those settings may claim applications for IWRM, but this is a matter of choice and not based on its unique properties.

The GWP was proposed during the 1990s by UNDP and the World Bank and has focused since then on development [27]. A detailed explanation of the forces and personalities that led to the GWP's creation has been provided by Allouche, who interviewed a number of the principal actors [28]. Prior to the formation and development of the IWRM tools and networks, most attention to water resources management occurred in science and engineering fields, but the situation has changed, and it is widely recognized that additional disciplines are involved with water management, especially because of its linkages to economic, social, and environmental issues. It is also recognized now that water is more than a resource or a sector, and is also a connector among sectors in health, food, energy, and ecology [9]. This concept is expressed by the nexus approach, which has become popular in recent years [29].

The GWP has a vision to use networks of IWRM practitioners to mobilize action for global sustainability and inclusiveness. Its claimed network of partners comprises over 3000 organizations in 180 countries, with 77 country water partnerships and 13 regional water partnerships. Becoming a partner is free, and governmental, non-governmental, and private sector organizations can participate. The country water partnerships are mostly with lower-income countries, and none are among the highest-income countries in North America or Europe. The GWP receives financial contributions from the European Commission, UN agencies, and several national governments, mainly from Europe. The 2022 financial report showed income from these sources of about EUR 13.6 million, with another EUR 7 million from locally raised sources [30]. GWP's reports show transparency, and their management and organizational issues can be assessed by reading them [31]. It is well to recognize that such donor-supported non-governmental organizations may experience change, which may affect promotion and support for IWRM in the future.

In addition to its partnership organizations, the GWP hosts a website to distribute IWRM information and tools. This resource has served to foster recognition of the IWRM concept, and it provides useful resources for education, training, and practice. It has been converted to an "Action Hub", which offers tools, case studies, and other resources. GWP has set a goal that the Action Hub will become recognized as the "most comprehensive knowledge repository on IWRM—the 'go to' place for those working in the water sector who want practical and evidence-based information to help them implement plans, policies, and projects." To foster cooperation among the IWRM community, GWP also aims for increased collaboration and to support partnerships with co-managed online communities [32].

4. Conceptualization of IWRM

The problem that spurred the initiation of IWRM as a development tool was the lack in many developing countries of the capacity to implement comprehensive systems for water resources management. Recognizing this gap, the developers of the IWRM concept studied how experiences in these countries could be assessed to develop an integrative method to combine water resource management and development. The resulting framework became popular due to institutional and personal efforts among thought leaders in the development community [28].

The thinking about IWRM's structure and methods was expressed in 2000 by the GWP Technical Committee (TAC), which issued a discussion paper in 2000 [33] to explain the definition and ideas about the IWRM concept and process, how to apply it globally, and how it could be implemented in different conditions. This bifurcation into global applications and those under conditions in different places aligns with the proposition of this paper that the IWRM framework can apply globally, but the IWRM process will depend on specific conditions where it is applied.

The GWP's TAC comprised fifteen members who worked from 1996 to 1999 to produce the discussion paper. The group has impressive experience, especially in global affairs that include development, environmental advocacy, non-governmental organizations, and academia. It is to be expected that it would have a clear view of high-level needs for water-related policies and institutions and that applications on the ground would be more difficult to frame due to their large number and diversity. However, IWRM is considered by some to be "an empirical concept which was built up from the on-the-ground experience of practitioners" [33]. That idea signals that the IWRM developers saw a widespread role for it.

The discussions make clear that IWRM as a concept has a broader scope than traditional views of water resources management, and it can be described by the categories of tools now offered by the GWP [34] (action hub): the enabling environment with policies, legislation, and plans; the institutions and participation with a range of political, social, economic, and administrative institutions and stakeholder groups; the management instruments for analysis and decision-making; and financing for development and management.

As outlined in the TAC's discussion paper, these attributes of IWRM were already evolving in the more developed countries by 2000, although all remained works in progress. This can be illustrated, for example, by the trajectory of water resources management in the US from early practices to the emergence of systems analysis during the 1950s [35] and then by comprehensive planning methods, which stemmed from policy studies leading to the US Water Resources Planning Act (WRPA) of 1965 [36]. These developments provided tools like use of economic, environmental, and social assessment from which broader tools and methods could grow. While IWRM was being developed, the search for other frameworks continued in parallel, especially about conflict resolution and the incorporation of social and environmental values in decision making. New paradigms that were developed with similarities to IWRM included Total Water Management [37], One Water [38], Total Water Solutions [39], and versions of systems engineering that seek the merge analysis of technical and socio-technical systems [40]. None of these frameworks has gained as much traction globally as IWRM, although in the US, the One Water concept is currently receiving emphasis.

The competing frameworks for integrative management differ in establishing system boundaries to indicate what is being integrated. This was a main issue discussed by the GWP's TAC [4] and later in the critique by Biswas [41], who expressed pessimism that IWRM would succeed and wondered how many things IWRM intended to integrate. His widely cited paper identified some 41 sets of issues that were to be integrated, including variables such as differing objectives, water and land, and water and health, among others. The inherent problem of the scope of system boundaries for IWRM is shown by its definition as a "... process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems [42]".

In addition to criticisms about IWRM's concept and methods and the need for more practical approaches [6,43], other criticism stems from differing perceptions, such as those focused on technical solutions versus social concerns like participation and equity [12,13]. The dichotomy between views was explained in [44], with one paradigm being labeled "predict and control" and another based more on participatory management and collaborative decision-making. The authors explained that perspectives from systems science and political science show a need for distributed and decentralized management to cope with complexity and uncertainties, and they recognized barriers due to gaps between scientific and political rhetoric.

These authors did not label the latter paradigm, but the term socio-technical might fit. They explained that such an approach will emphasize integration of issues and sectors, management of problem sources rather than effects, decentralized and flexible approaches, attention to management of behavior by soft measures, inclusion of the environment in goals, transparency, and iterative learning. They also acknowledged that local solutions, such as in small basins, will work better than those at larger scales, where some centralization is needed for problems like transboundary and standard setting. This observation aligns with the writer's experience that collective action in water management works better at local scales than at larger ones [45]. A study of the founding documents of IWRM shows, of course, that the creators of the concept recognized these views.

How IWRM relates to the nexus concept and how the two concepts can be merged have also been studied [3]. Nexus terminology was not in popular use when the IWRM concept was developed, but it seems clear now that the arenas of water management application will fit the definition of a nexus, which will contain elements that correspond to the situation at hand when IWRM is applied.

The two functions of IWRM can be diagrammed to illustrate their differences and how they respond to the diverse needs of water-related situations and conditions. Figure 1 illustrates the framework function on the left and the process function on the right. The framework concept is taken from the GWP's explanation on its Action Hub [34] and is identical to the way that its Technical Committee has evolved the classification of IWRM

tools. The dashed line indicates that the four elements are connected by IWRM. The process version is taken from a concept expressed by the US Environmental Protection Agency for a collaborative problem-solving process that can be used in environmental justice situations [46] and follows the general sequence that has proved useful in diverse situations. The dashed line indicates the general sequence of the process. The two functions of IWRM have shared features in their intent to promote both the development and management of water, land, and related resources, where the nexus examples can be natural assets like forests and fisheries, or they could be socio-economic assets, like job-producing industries [3].

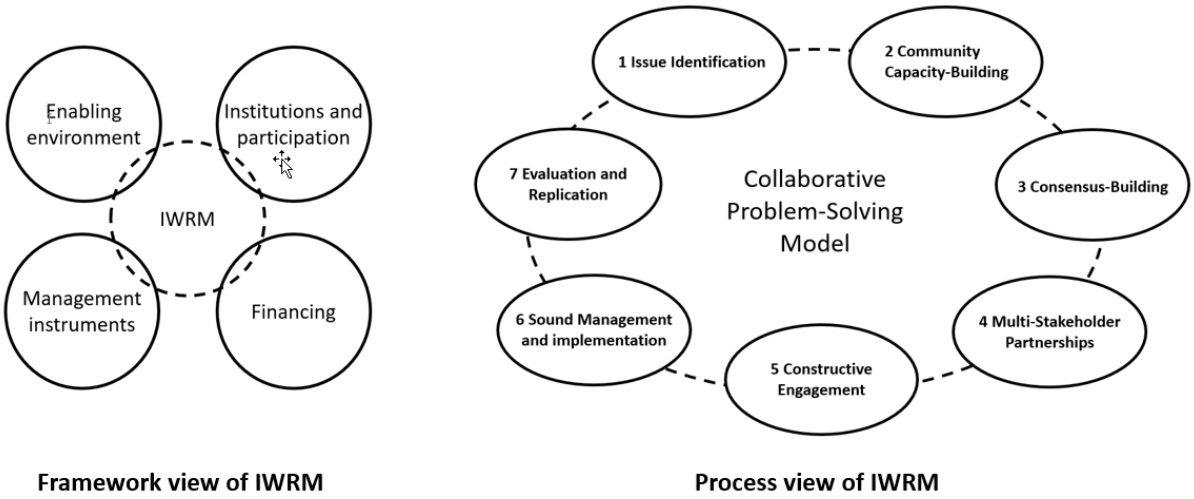

Figure 1. Framework and process views of IWRM.

5. Assessing Success of IWRM Implementation

Because the implementation of IWRM was made a target of the SDGs, it is necessary to measure its degree of implementation. This presents a challenge due to its scope and influence across multiple SDGs, but also because, as the IWRM creators wrote, "Whether or not IWRM has brought about changes that would have appeared anyway as a result of the co-operation of dynamic professionals and politicians with vision and common sense will never be known." That view seems to address the overall concept of IWRM, whereas their other observation seems to point toward the process view of IWRM: "A comparison of the 'with IWRM' and 'without IWRM' situation can, at best, be speculative. The very least that IWRM does, is to remind the practitioner about a number of good—and generally accepted—principles. . ." [33].

The task of assessing IWRM's impact can benefit from dividing it into two functional areas. The framework view is broad and already represents the view of Benson et al. [3], who thought that it should be re-conceptualized and that assessment should extend beyond the water centric form of IWRM to consider its contributions to accounts such as poverty, clean and affordable energy, gender equality, protecting ecosystems, sustainable cities, hunger, climate change, and strengthening global partnerships. Even with a water-centric approach, assessment requires triangulation to view it from different viewpoints, primarily through the use of indicators, case studies, and the research literature base.

Indicators of IWRM implementation are accessible via the SDG reporting system [47], which mainly addresses its framework function. The primary point for assessment is SDG Target 6.5: "By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate." Indicator 6.5.1 is "Degree of integrated water resources management implementation (0–100)." Country data can be downloaded from the data portal. The most recent analysis in a 2023 update on progress indicated that the rate of implementation of IWRM is too slow and that 30 years after the 1992 introduction of IWRM, some 87 countries still report low or medium-low levels of its implementation. The scoring levels are via a questionnaire managed by the UN Environment Program (UNEP), which goes to ministries, along with stakeholder consultations.

The survey organizes information by the GWP toolset categories for enabling environment, institutions and participation, management instruments, and financing, and it has a section about sub-national, basin, local, and transboundary levels to report about basins, aquifers, and jurisdictions. By necessity, the questions are generalized, like "What is the status of policies, laws and plans to support Integrated Water Resources Management (IWRM) at the national level?" and "What is the status of policies, laws and plans to support IWRM at other levels?" The scoring of survey responses is by expert judgement or stakeholder consultation [47]. Questions about management instruments are generalized about management issues at the national level, like pollution control, and at other levels about issues such as basin management methods.

IWRM cases, as posted by the GWP, by UN Water, and by writers who publish studies in the research literature, reveal the diverse strands of IWRM. When cases are submitted by writers like the GWP cases, they reflect the process function. Those prepared by the UN mostly express the framework function.

The 259 reports currently on the GWP website were downloaded for analysis. They have dates ranging from 2008 to 2024, with a peak in 2013 when some 113 of the cases were posted, with diminishing numbers afterwards. This time pattern seems to reflect the times of screening of the cases by GWP rather than trends in interest in IWRM among users. The writer's inquiry to the GWP staff indicated that with the recent move to the Action Hub format, the cases were reviewed, and some older ones were removed. Anyone is free to submit a case study on the Action Hub, and these are reviewed internally for quality assurance and, in some cases, may be revised slightly. Generally, posted cases must illustrate the application of at least one of the tools, reflect principles and expand on lessons about water management across sectors, describe successes and failures, address key issues in the water community, and be broadly relevant with the potential for wide dissemination [48].

The distribution of the cases showed 102 from middle-income countries, 71 from low-income countries, and 38 from high-income countries. There were 39 transboundary cases and 9 about regional or generalized situations, like policy development. The medium-income cases included eleven from India and six from China. Most of the lower-income cases were in Africa or Asia. The high-income cases included only one from the US and none from Canada.

An attempt to classify the cases by topic proved impractical because of the diversity of subjects. The GWP indicates which management instruments apply in each case, but this information seems incomplete and impractical for classification. Water management cases had been classified previously by the writer into eleven categories [49], but many of the cases exhibit attributes of multiple categories. The new curator tool on the GWP website offers more categories, but it will still be difficult to assign only one category to a case. This tool is explained in the discussion section of the paper.

Each case can involve variables for system purposes, management methods and functions, stakeholders, institutions and authorities, sectors involved, scales, and stage. These variables involve multiple degrees of freedom and are somewhat interdependent, such as stakeholders being associated with sectors and with geographic areas, which are associated with scales. These degrees of freedom and interdependencies are a major cause of IWRM's complexity and lead to different interpretations of it.

In terms of the situations reported, the GWP cases exhibited wide diversity in the subject matter variables as they addressed situations like erosion control, water data systems, government leasing water systems and operators, new water legislation and regulations, river and estuary restoration, and national water framework plans. None of these situations are unique to IWRM because they were well known and explained prior to its emergence. While each case normally involves stakeholder involvement, many deal very little with social problems in communities, which is a main distinction between IWRM and other paradigms of water resources management.

While no consistent pattern was evident among the GWP cases, six examples were selected to illustrate how the case authors perceived their situations to reflect IWRM. One case is from a low-income country, two from middle-income countries, for which there were most cases, one from a high-income country, and one from a region involving several countries. The examples were selected to represent a cross-section of applications and to demonstrate typical attributes of IWRM. Dates range from 2008 to 2014, or from ten to sixteen years ago.

The low-income country case submitted by a non-governmental organization based in London [50] is about the National Water Management Plan (NMWP) for Bangladesh, which was published in 2004. The case explained the development of the plan, which had focused earlier on structural measures but shifted toward emphasis on social justice, equity, and poverty alleviation. There was extensive stakeholder involvement in the development of the plan [51], and the shift toward social participation is attributed to the use of IWRM methods [52]. An assessment of the plan showed that transitions in policy, institutional arrangements, and projects as key dimensions of IWRM are well represented, but they occur more at the policy level than with projects [53]. This view was reinforced by the WARPO [52], which reported that the NWMP was not implemented adequately due to institutional bottlenecks. This is an example of the common problem of interagency coordination, and the conclusion was that achieving the overall objective of the NWMP is well short of its vision.

The author of the middle-income case in Egypt represented the country's Ministry of Water Resources and Irrigation. Egypt's growing population and need to strengthen food security call for increasing water use efficiency by improving irrigation methods and management. Recognizing the challenges, Egypt has had an ongoing Irrigation Improvement Project (IIP), with successive phases stemming back to the 1970s. The IIP initially emphasized rehabilitation of irrigation networks, and after the late 1980s, donors assisted it in capacity building and the organization of Water User Associations (WUAs). Now, the case reports that farmers respond to market forces in determining cropping plans, and the government works with the WUAs to coordinate cropping patterns and water resource management. In a recent survey, researchers found that farmers credit the WUAs with improving social interaction, especially in reducing conflicts over water, and they believe that the associations also improve awareness of environmental issues, although such awareness can be improved [54,55].

The author of a second middle-income country case is with the Manila Water Company, which assumed control of water and sewerage utilities from the state-owned Metropolitan Waterworks and Sewerage System. At the time of privatization in 1997, estimates were that only 26% of the 3.1 million customers had continuous water availability, and only 3% had any sanitation services. System losses were around 66% due to leakages and water theft, but the government could not increase water tariffs. Debt was around USD one billion and was backed by the government by relying on taxpayers. [56,57] A case prepared at the Harvard Business School reported that privatization led to an impressive and profitable performance [58]. Manila Water collaborated with ADB to produce a book about change management and the utility. Like other large cities, water crises due to climate change and drought do occur, and public communication about them is important but challenging [59].

This case contrasts with one that occurred in Cochabamba, Bolivia, where privatization led to a citizen revolt and was reversed. Bolivia is a lower income country and has a different culture, but a comparison of the methods used by the utility companies might provide useful insights into the needs to support success in water system privatization under different scenarios [60].

The high-income case selected is from France, where an author with the Ministry of Agriculture explained the over-drafting problem with a regional aquifer in the Béziers region, near the southern coast of the country. The population depending on the aquifer increases from 180,000 to 300,000 during the tourist season, and development of the aquifer has been uncontrolled with around 600 wells in operation. The overuse of the aquifer

caused a decline in the water table and increased the risk of saltwater intrusion. A comprehensive management policy was advocated, and a syndicate of local authorities was established in 1990 for aquifer management. The syndicate, which is similar to a water user's association, had stakeholder representation comprising state and water agency authorities, local authorities, and water users. They have developed a coordinated management plan, which seems successful in protecting the aquifer except that it does not regulate small wells, which are difficult to manage due to private property rights [61].

Transboundary cases are appropriate to demonstrate IWRM applications because there are many instances and cooperation is lacking in most countries. Some 153 countries have parts of at least one of 286 transboundary river and lake basins and/or 592 transboundary aquifers [62]. Oregon State University [63] posted a database of transboundary treaties, and 14 were discussed by Wolf [64]. The transboundary case chosen is a large regional groundwater system, the Guarani Aquifer, which covers more than 1 million km^2 of Brazil, Paraguay, Uruguay, and Argentina. Some 62% of the land area is in Brazil. The aquifer has major potential for municipal and industrial water supply, irrigation, and geothermal energy. It has around 2000 operating deep production wells and serves a population of around 15 million directly, but nearby large cities increase the potential service population substantially. Coordination in the water uses was problematic, but the Global Environment Fund provided funding for a project for groundwater management, which demonstrated through pilot projects how local management should be organized. This established a core of tools for the countries to build on. It led to a specific agreement, which is rare globally for transboundary aquifers. Initial optimism has subsided and progress has been slow, but a basis for progress has been established [65].

The regional cases reflect common water management situations across several states where a central water authority is lacking. The case chosen is in West Africa, where the author is a representative of the GWP and reported a process that was initiated at the 1998 West African Conference on IWRM in Ouagadougou. Seven countries participated, including Côte d'Ivoire, the Gambia, Guinea-Bissau, Guinea, Liberia, Sierra Leone, and Togo. The countries reflect diverse situations, such as in Sierra Leone, which faced a rebuilding challenge after years of civil unrest. Plans at the time focused on single purpose water uses such as water supply, hydropower, and irrigation, with less emphasis on institution-building. The conference noted that such emphasis on single purpose projects placed a barrier to the implementation of IWRM due to a weak policy and regulatory framework, resulting in fragmented responsibilities and operational problems [66].

Table 1 provides a summary of the six GWP cases that were discussed as a sample of the many cases posted over time. They were contributed by diverse sources and lack a classification, but they indicate how IWRM tools can be applied across many different situations and contextual arrangements. They range in scale as shown, and water management topics include multi-sector national water policy, management of small-to-large regional aquifers, food security and farmer participation, large-scale urban issues, and regional multi-sector water management in West Africa. The diversity of the scales and sectors involved illustrates the difficulty in classifying IWRM applications.

UN cases about the application of IWRM are mostly reports about ongoing policy or planning activities. They date to the 2008–2014 period and were prepared to support UN programs, such as the Commission on Sustainable Development in 2008 [67]. That report described the results of a survey of 104 countries, of which 77 were developing IWRM approaches or were in transition, and another 27 countries reported they had developed their programs. Questions at the national level were very general and asked if IWRM had been implemented. The mixed responses referred mostly to national policy issues rather than on-the-ground implementation. For example, a report about countries in Eastern Europe, the Caucasus, and Central Asia pointed to revision of water codes, the organization of river basin councils, and the development of river basin plans. It used a discussion format and credited progress to the EU Water Framework Directive and the ECE Water Convention [68]. No follow-up report has been identified to indicate how well the

activities have been sustained, although it is likely that the policy and planning activities are continuing.

Table 1. Summary of the sample of six case studies posted by the GWP.

*	Case	Year	Scale **	Description and Status
L	National Water Plan of Bangladesh	2013	N	National policy/plan for water resources. It preceded IWRM, but recent shifts are toward social issues and away from emphasis only on infrastructure.
M	Egypt water user associations	2013	N	A national irrigation capacity-building program that began prior to IWRM but with recent shift toward social actions and support for market-based agriculture.
M	Manila Water	2014	U	Privatization of a major urban water utility with reported successes based on improved management actions.
H	France groundwater management	2008	RS	Organization of a syndicate to develop cooperative management of shared aquifer in a small coastal region.
TB	Guarani Aquifer	2010	RL	Development of international agreement to manage a large regional aquifer. Implementation remains slow despite donor involvement over long period of time.
R	West Africa	2013	RJ	Efforts to cooperate in application of IWRM among neighboring states with similar issues and problems. The countries face major problems in institution-building.

* L = low income; M = middle income; H = high income; TB = transboundary; R = regional. ** N = national; U = urban; RS = small regional; RL = large regional; RJ = regional by jurisdiction.

Another example of cases within the UN agencies is from the Associated Programme on Flood Management (APFM), which defines its framework for Integrated Flood Management (IFM) as part of IWRM. IFM lacks its own SDG, but flood risk reduction is included as a target under SDG 11, Sustainable Cities and Communities. Indicators are deaths and injuries from natural disasters, economic losses from natural disasters, damage to critical infrastructure, and disruptions to basic services [69,70].

In cases of IFM, the main indicator of integration is a flood risk reduction strategy that has more than a single structural method. Case studies about flooding were collected as the AFPM developed the framework for IFM and were included in its strategy paper some 20 years ago [69]. The cases were like those posted by the IWRM Action Hub, and they were used to study the range of flood issues, to include areas, populations, numbers of flood events, severest events and years of occurrence, impacts, and damage losses. Due to the social impacts of flooding, the cases did address vulnerabilities and non-economic loss issues.

Additional cases to demonstrate the outcomes of IWRM are in research publications, which also feature diverse situations but without a consistent framework. Like the GWP cases, many reports offer examples that reflect different claimed applications of IWRM, but few started with the deliberate goal of studying the situations through an IWRM lens. The exceptions are development-oriented projects where project teams sought to apply IWRM methods from the start. To illustrate, a selection of eight reports has been assembled into Table 2. These are not offered as a complete analysis of cases claiming IWRM in the publications, but they are meant to provide a range of typical examples.

Table 2. Sample of typical IWRM case studies posted by individual authors.

Analysis and assessment of IWRM	The analysis of several cases showed that claims of success depend on historical situations. It found fault with claims of different ways to implement IWRM according to development stages. The writers argued that lack of an unambiguous definition causes problems and is a barrier to implementation [71].
General review of ten situations in five continents	A published volume drew cases from five continents to explain ten highly diverse situations ranging from national policy development to small scale examples [72]. As in other publications, the examples cite water management situations that could be reported without claiming application of IWRM.
General review of seven water management situations in the US	A report of seven cases in the US concluding that IWRM was being applied, although none of the cases involved intentions to apply it. The report indicated a plan to build on the IWRM approach to create a national water vision and strategy, but there is no indication that this visionary plan has occurred some 12 years after publication [73].
Cases in the development context	Researchers published five cases that illustrated how IWRM can be applied to diverse development projects [74]. This is an example of how IWRM claims about development projects indicate the main intent of the framework from its inception, to be applied for developing countries.
Case of a national program in Myanmar	A study in Myanmar studied IWRM status in 2014 but indicated lack of financial support and political will. The researchers noted public need for access to hydrological information and to social equity criteria [75]. This example views the actual national situation through the lens of IWRM tools.
"Practical" IWRM approach	Researchers used experiences from developing countries to propose a "practical IWRM approach." They found that IWRM was ideologically accepted, but the GWP definition leads to misconceptions and problems because precise methods and goals are lacking. They saw possibilities for success in simple situations [76].
IWRM in rural areas	Researchers found that large rural population are not aware of IWRM principles despite their roles as key stakeholders in basin management. They noted a few cases where inclusion of stakeholders showed promising results [77].
Case of legislation in Colombia	A project in Columbia in 2004 drafted a new law to implement IWRM in national legislation. The law was not implemented, and the nation already had significant legislation that had not been implemented [78].

All reported cases that were reviewed are narratives, and their objectivity and assertions are mostly unverified. Formal case study research methods could provide more rigor, but no such studies were identified. Scenarios of IWRM cases could be constructed by combinations of variables such as scale, purpose, and socio-economic status, but the diversity of cases and multiple factors involved would make the classification highly complex and non-unique [49]. As an example of non-uniqueness, the celebrated case of Singapore Water overcoming scarcity through an integrated approach [79] can be claimed as IWRM or systems engineering [80].

Cases describe many situations and can be used to assess how well IWRM is working, but a case might be identified as showing how IWRM works while other management frameworks might claim the same case. For example, the successes of water management in Singapore have been claimed for both IWRM and systems engineering as a method [80].

In addition to uncertainties about case study reporting, assessing the success of IWRM is problematic because its implementation is normally a work in progress and outcomes are uncertain. Many reports about IWRM involve long-term activities such as policy development, planning, and research, and results cannot be determined on a timely basis. In most cases studied for the paper, the use of IWRM was not specified as a definite method, but the writers describe the situation and indicate that it illustrates how IWRM works. Attributions to IWRM can be arbitrary, and claims of outcomes depend on who reports them and why they might do so.

6. IWRM Education and Training

An important measure of the success of IWRM is its success in penetrating the arenas of academic education and professional training. Given the diverse understanding of what IWRM is, it is expected that determining how to teach it to university students or organize training programs would face barriers. As an interdisciplinary field, it lacks a professional association, a body of knowledge, and any standards to certify professionals. IWRM could have such a structure as, for example, the interdisciplinary field of public administration has.

There is no central registry for information about education and training in IWRM, but the writer has experience with both and conducted an Internet search to sample current program availability. The search showed that only a few university-based programs are in operation, and they focus on developing countries. The curricula appear to focus on water resources engineering and science, with fewer courses in the social sciences. A prominent example of university programs is the four-semester master's program at the TH Köln (Technical College at Cologne), which offers choices among programs and study abroad opportunities [81]. The program seems unique in its breadth and the commitment it receives from its home institution. Several master's programs were identified in Africa and Asia, but their status is unknown. The University of British Columbia has a master's program, but it has been paused pending a study of its effectiveness [82].

The writer also identified only a limited set of training courses offered within the UN system and by other purveyors, with courses ranging from a few days to multiple weeks. These are like the donor-supported courses offered at the writer's institution over several decades. The courses lead to certificates of completion, although no standards exist for the instruction. If standards were developed, they might mimic the training provided by GWP [83], which provides guidance on items in the Action Hub. Also, the Stockholm International Water Institute has developed a training manual that links assessment criteria to outcomes in categories that include defining water resources, explaining the approach and key principles of IWRM, and exploring case studies of implementation [84]. Although developed for a development project in Ethiopia, it might serve as a starting point to develop a generalized body of knowledge for other applications.

Other courses vary in length and content, which will depend on the expertise and experience of the instructional staff and not necessarily align with the GWP expressions of the IWRM approach. Some of the online courses are self-paced and free of charge; some are both online and onsite and have a fee; and some are online only for a fee. Courses with some subsidies can be expected to continue, but fee-based courses will be offered based on demand and may not be sustained.

The courses and programs currently on offer illustrate different approaches. They might explain the IWRM approach, usually as developed by the GWP, or they might bundle an introduction to it along with basic instruction in topics like water sciences and economics. In most cases, public engagement and equity issues are stressed. Every program will make extensive use of case studies. These attributes lead to a suggested model for education at the university level, which is to use the basic IWRM approach as an interdisciplinary glue to hold other subjects together, to offer mixed packages of courses in supporting disciplines like science and economics, to stress the social issues prevalent in the world of water, and to use case studies to provide students with examples of how IWRM should work in different settings.

Use of the phrase IWRM in courseware implies acceptance of the GWP definition and approach, which is not universal. The general concept of water resources management seems easier to accept, even though perspectives differ about what it means [85] and it may not include the nexus among water, land, and other resource sectors. The list of UNESCO [86] Chairs shows water-related topics, and many involve topics that could be used in IWRM instruction, such as integrated river management, conflict resolution and transboundary water governance, hydropolitics, and sustainable water services, among others. As an example of broad water resources education, not labeled as IWRM, the

disciplines that participate in the Universities Council on Water Resources (UCOWR) include engineering, biology, chemistry, geography, political science, sociology, economics, and environmental health, among others.

Continued effort will be needed to maintain focus on the IWRM approach in education and training. Without such a focus, water resources management will be splintered among many disciplinary topics and perspectives, which might be a barrier to improving the workforce and progress toward the SDGs. Any university-level programs should offer academic as well as practical content or be "pracademic" [87]. Training programs for practitioners could focus on practical situations using case studies. A clear distinction between the IWRM framework and the IWRM process will help in developing curricula.

7. Discussion

The evidence indicates that IWRM and its tools offer a comprehensive approach that can benefit users in all countries, but the challenge is to sustain and increase use of them, thus extending their reach and enriching their knowledge base through collective action. The major issue in sustaining and increasing support is clarification and messaging to increase acceptance by professionals, the public, and policymakers [88,89]. The GWP definition of IWRM is institutionalized, but it is vague and open to different interpretations. Its integrative attribute makes it broader than other frameworks for water resources management that lack the nexus concept. Messaging can be clarified by succinct explanations of IWRM goals, what it is intended to do, and how it should be used. Most important in the messaging is to explain it in terms that people care about, like drinking water, stream health, flood risk, and food security.

The GWP does provide clarifying language to address the ambiguity of its definition. For example, "IWRM should be viewed as a process . . . that is long-term and forward-moving but iterative rather than linear in nature. There is not one correct administrative model. The art of IWRM lies in selecting, adjusting, and applying the right mix of tools for a given situation" [90]. The new Curator tool on the IWRM Action Hub extends this effort to clarify applications in diverse settings by identifying how they align with problem types. The Curator offers 21 choices for the question, "what would you like to do?" [32]. These choices are displayed on Table 3 in six categories, which illustrates how most choices are for policy and management situations. The choices exhibit the functions involved in IWRM settings, but other variables include water management purposes, scale, and stage of the actions, among others.

Table 3. Classification of 21 IWRM Curator choices into six groups.

Management	Policy and Regulation	Planning	Stakeholder Engagement	Equity	Finance
Manage water supply	Create policies	Water plans	Coordinate stakeholders	Include gender	Investment rationale
Build capacity	Legislation	Assess integration	Transboundary cooperation	Promote social change	Financing strategies
Make decisions	Water use regulation	Water and climate	Enhance water dialogues		
Enhance efficiency	Protect ecosystems				
Create incentives					
Engage private sector					
Manage disasters					

These curator choices are a mixture of IWRM framework and IWRM process, and they might be improved by choosing verbs that distinguish between establishing institutions and solving problems.

Given the many instances where IWRM framework can be used, assessing its implementation and success will continue to pose a challenge, but its tools offer a way to assess progress toward sustainable development via SDG Indicator 6.5.1 [47]. As mentioned earlier, progress is assessed by general questions directed to country representatives, but staff turnover among the reporting agencies and the possibility that national staff lack the full picture of activities at the regional and local levels increase the likelihood that implementation statistics may be unreliable. As an example, the on-site study of IWRM implementation in Colombia indicated that many institutions were in place. However, the actual operations and outcomes were problematic due to governance and political issues in the country [78].

As would be expected, most countries showing the highest scores on SDG 6.5.1 are higher-income, and those with the lowest scores are low-income. The highest scores were for France and Singapore, both with 100. The US score was 77, compared to the global average of 57. Scoring the US this result raises questions because an accurate score would require surveys of all states and territories, which would take a major research effort. As the US does not use the phrase IWRM very much, it is apparent that the score reflects the opinions of selected officials and stakeholders about the general status of the enabling environment, institutions and participation, management instruments, and financing. The complexity of assessing these categories in a major jurisdiction like the US illustrates the inherent difficulty in assessing SDG indicator 6.5.1.

Using case studies to assess progress is also problematic because they are not quality-assured and their status is generally unknown, especially among older cases. As noted earlier, the original IWRM creators recognized that the with- and without-assessment of IWRM will always be problematic [33].

Given the challenges of assessing both the IWRM framework and the IWRM process, it is not surprising that progress in implementing the IWRM as indicated in the survey report on Indicator 6.5.1 [47], has been slow, even after 25 years of work. This rate of progress mirrors the pace of economic and social development in many countries and in achieving the SDGs.

If progress on IWRM continues to be slow and uncertain, does its community have the staying power to sustain its identity for the long term? Its future is linked to the GWP, which is funded by donors, and to the SDGs, which will expire in 2030 and currently lack a clear path from there [91]. Despite criticism of the SDGs, it seems likely that a version of them will continue to offer an overall and unifying framework around the shared goal of sustainable development, and IWRM or a replacement for it will continue to be needed. The need for renewal of IWRM was also evident in a recent meeting of the donors of the GWP, which exhibited concerns about funding and organizational issues [31].

The GWP was founded as a partnership, and with its networks, it aligns with Goal 17 of the SDGs, "Revitalize the global partnership for sustainable development" [92]. This is a multifaceted goal and much of it addresses development assistance flows from developed to developing countries, but it also involves capacity-building, such as in target 17.9, "Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals…"

Other partnerships for capacity-building offer suggestions for ways to sustain the IWRM community as a whole. For example, the US Partnership for Safe Water program, sponsored by the American Water Works Association, provides for assessment and credentialing. Such credentialing could be an incentive to implement IWRM, but attracting participation in the host partnership programs is challenging because utilities do not always sense enough incentives to attract them to participate [93]. In the case of national credentials for IWRM, the incentives might prove to be stronger. Should constraints arise to inhibit GWP's ability to sustain IWRM knowledge resources and its networks, new partnerships and a credentialing program offered by an international water association offer attractive options to continue the efforts.

Given their linkages to the UN system and to donors, the SDGs and IWRM will continue to offer valuable resources for countries with developing water institutions. However, they have not gained much traction among communities with established policies and management practices, as illustrated in the US, where the One Water paradigm has surpassed the popularity of the IWRM label. In fact, residents in higher-income countries also show less awareness of the SDGs than those in lower-income countries [94].

If the acceptance and usefulness of IWRM are to be increased, leadership and advocacy will be needed to recruit and educate new and rising water leaders and citizens. Interdisciplinary education for IWRM must confront disciplinary stovepipes, and the knowledge resources provided by the GWP can serve as glue to foster a comprehensive approach. Without such a focus, education and training in IWRM and in general water resources management may continue to be splintered and form a barrier to improving the workforce and progress toward the SDGs. While academics and thought leaders can continue to criticize IWRM and offer new frameworks, unifying on IWRM can provide a common meeting ground for the exchange of ideas and new ways to achieve shared goals. The fact that water is a main resource that cuts across all SDGs underscores its importance in progress toward sustainability. As IWRM educational systems have not been developed, a coherent strategy to build on them for the future is needed and will require cooperation among stakeholder groups moving forward.

8. Conclusions

The review showed that IWRM is a multi-faceted concept that cannot be understood simply from its definition and brief explanations. Its definition indicates that it is a process that combines a comprehensive approach to water resources management with a nexus with interdependent sectors. However, IWRM involves more features than those, and the principal one is that it provides a framework to assess how countries and their water management subunits fare in terms of their enabling environments, institutions and participation, management instruments, and financing to support development goals. While the term "process" has been in the IWRM definition for over two decades, recent developments in the assessment of SDG goals focus on it as a framework of institutional arrangements for water resources management to support various sectors. This does not mean that the term process should be replaced in the definition because users who require guidance in implementing integrated approaches need a process-based structure for their planning and execution. The model process shown in Figure 1 would be a good way to express this functionality.

IWRM can benefit stakeholders in all settings, but the challenge is to sustain it and extend its reach and knowledge base. With its multi-pronged tools for application, it can add value to traditional water resources management via its nexus of water, land, and related resources. Some writers questioned if the IWRM framework is conceptualized effectively and why criticism continues such that thought leaders do not rally around the concept. The review pointed to the need to address such divergence of opinion by improving messaging about IWRM and finding more effective ways to implement education and training for it.

SDG reports indicate a slow pace of implementation of IWRM, but the cause seems to stem more from the pace of improving governance than from acceptance of the IWRM identity and methodologies. This indicates a divergence between the identity of IWRM as a conceptual framework and its elements, which will survive no matter how they are identified in any conceptual framework. The status of IWRM as a principal organizing framework does seem stable, but its longer-term prospects depend on the international development agenda and support by the GWP and donors.

The difficulty of achieving objective ratings of IWRM implementation across diverse countries reflects its complexity, which is also evident in case reports about many dissimilar situations. Using cases to assess the success of IWRM efforts is problematic because they are often works in progress with uncertain outcomes. The broad and ambiguous conceptualization of IWRM that causes the difficulty with assessment opens the door to

continued criticism about it. This could create a healthy dialogue, but it has continued for a long time, and some thought leaders felt fatigued about the subject.

The current institutional arrangements to support IWRM depend on UN agencies, the GWP, and donors. As these arrangements have provided support for a long time, there is reason to expect they will continue to benefit global water-related outcomes. The GWP Action Hub offers useful tools, case studies, and other resources, and it has a goal to become recognized as the "most comprehensive knowledge repository on IWRM—the 'go to' place for those working in the water sector who want practical and evidence-based information to help them implement plans, policies, and projects." Such an ambitious agenda could have widespread benefits for the global water management community.

The literature indicates that IWRM needs improved messaging, and a start for this is evident with the new Curator tool on the Action Hub site. By expanding this tool to accommodate the diverse attributes of IWRM applications, case studies can be mined to create lessons for users through emerging artificial intelligence applications. Improved messaging will help professionals and stakeholders address their water-related problems, especially if social issues can be addressed effectively. This can respond to critics who say that IWRM is confusing or that it is hegemonic and biased toward professional viewpoints at the expense of disenfranchised people.

An important measure of the success of IWRM is its success in academic education and professional training. There is no central registry for information about education and training in IWRM, and the inquiries made during the review show a scattered and limited approach.

Without acceptance of IWRM in education and training, water resources management will continue to be splintered among many disciplinary topics and perspectives, which might be a barrier to improving the workforce and progress toward the SDGs. Cooperative work to develop a body of knowledge and educational systems for IWRM can promote more acceptance in education and training, and future research and engagement will be required to support it.

While the pace of progress with IWRM will likely remain slow, its supporting community will need the staying power to sustain it for the long term. Should emerging constraints inhibit GWP's ability to sustain IWRM's identity, knowledge resources, and networks, new partnerships and a credentialing program offered by an international water association might offer attractive options to continue the efforts. As neutral meeting places, water associations like the International Water Association and the International Water Resources Association are positioned well for promotion of partnerships and credentialing, which would require standards and a body of knowledge.

Pursuing the goals of IWRM will be a long-term process, and a road map is needed for nations, regions, and localities to develop effective and comprehensive approaches. Institutional arrangements at the national level are essential, while IWRM-fostered collective action works best at local scales. The major issues moving forward seem to be developing improved conceptualization and explanations of IWRM, followed by better messaging to increase its acceptance among professionals, the public, and policymakers.

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