Paper Title: Engaging the Earth Science and Engineering Communities in Developing a River Morphology Information System (RIMORPHIS)

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Engaging the Earth Science and Engineering Communities in Developing a River Morphology Information System (RIMORPHIS)

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Research Impact Statement: This study developed and implemented strategies for engaging the broader earth science and engineering communities in prototyping a web-based river morphology information system.

ABSTRACT: River morphology data are critical for understanding and studying river processes and for managing rivers for multiple socio-economic uses. While such data have been acquired extensively over time, several issues hinder their use for river morphology studies such as data accessibility, variety of data formats, lack of data models for data storage, and lack of processing tools to assemble the data in products readily usable for research, management, and education. A multi-university research team has prototyped a web-based river morphology information system (RIMORPHIS) for hosting and creating new information and data processing tools to be shared with the broader earth science communities. The RIMORPHIS design principles include: (i) broad access via a publicly and freely available platform-independent system; (ii) flexibility in handling existing and future data types; (iii) user-friendly and interactive interfaces; and (iv) interoperability and scalability to ensure platform sustainability. Development of such an ambitious community resource is only possible by continuously engaging stakeholders from the inception of the project. This paper highlights the research team's strategy and activities to connect and engage with river morphology data producers and potential users from academia, research, and practice. The paper also details outcomes of stakeholder engagement and illustrates how these interactions are positively shaping RIMORPHIS development.

(KEYWORDS: geomorphology; data management; rivers/streams; scientific community engagement; hydroinformatics)

INTRODUCTION

Stream morphology information is among the most critical data needed in the water resources sciences as it describes essential features such as channel and floodplain geometry as well as cross-sectional and longitudinal profiles and the characteristics of the river boundary materials. Historically, these data have had a wide range of uses including rainfall-runoff modeling (Ewing et al., 2022), flood inundation mapping (Li et al., 2022), culvert and bridge design (Xu et al., 2019), climate and land use change studies (Liébault et al., 2005), channel stability and sediment source investigations (Recking et al., 2012), navigation studies (Ten Brinke et al., 2004), and habitat assessments (Mounton et al., 2007). In the United States, the need for stream morphology data has grown substantially over the last few decades because of the increasing interest from resource management agencies in watershed stewardship and from scientific groups to better resolve still unknown geomorphological issues (Kondolf et al., 2007). Fortunately, the quantity and quality of stream morphology data have continuously improved with the adoption of state-of-the-art technologies capable of rapidly collecting data with high spatio-temporal resolution over large spatial extents in a variety of river sizes (Collins, et al., 2012).

Stream morphology data are collected across the nation by federal and state governments, academia, non-governmental organizations, and groups within the private sector to address current watershed resource challenges. Data collection is unguided by common reporting standards and lacks easily accessible mechanisms for archiving and disseminating datasets that are often spatially complex. Moreover, the recent advancement of data collection technologies (e.g., terrestrial lidars, hydroacoustic instruments, remote sensing) has led to an unprecedented volume of stream morphology data in a variety of formats that challenge our current data-handling capabilities (Muste et al., 2017). This situation is present at all scales and true of most stream-related research and monitoring agencies, making it difficult to store, access, search, visualize, or retrieve geomorphological data of interest for solving problems in specific streams.

Currently, the cumulative interventions of humans on the earth systems are outweighing the natural changes leading to impacts on virtually all earth environments (Meadows & Lin, 2016). Scientists are using increasingly sophisticated technologies in geomorphological studies to detect and quantify evolving human-induced changes in landforms such as acceleration of soil erosion over landscapes, reduced transport rates due to construction of large hydraulic structures in rivers, and creation of artificial grounds through earth material extraction and deposition. These emerging technologies span from traditional field techniques and conventional data collection to the use of remote sensing (Li and Demir, 2023) supported by geographical information systems, and computer-aided techniques for geostatistical analyses (Shahid et al., 2023) and dynamic modeling. The disparate nature of the principles, methods, and tools associated with these quantitative geomorphologic assessments also requires reaching across technological domains.

Given that the impacts of geomorphological processes entail socio-economic sciences in addition to other traditional disciplines in natural and physical sciences, river morphology data are used by people with different expertise to conduct disciplinary and interdisciplinary projects. Garnering of data resources required for investigating geomorphological processes with a societal perspective is a “big-data” type endeavor that must include ecological and economic aspects such as prediction of equilibria in disturbed natural systems and attaining sustainable goals through intervention, prevention, and reclamation (Kondolf & Podolak, 2014).

Following a preliminary earth science community engagement effort led by the Subcommittee on Sedimentation (SOS) of the US Advisory Committee on Water Information (ACWI) (Collins, et al., 2012), a multi-university team, led by the authors, has been working since

2020 to create a self-sustained community platform to enable access to river morphology data. Besides providing data access, this platform, named River Morphology Information System (RIMORPHS), will have tools for supporting integrated multidisciplinary research and practical applications in riverine environments. RIMORPHIS is designed with a structure as follows: (i) open, integrated, and platform independent; (ii) flexible and adaptable to new types of data and operational capabilities; (iii) simple to encourage contributions from a wide variety of stakeholders; (iv) responsive to the needs of multiple end-users with diverse technical backgrounds; and (v) interoperable and scalable to sustain beyond the project duration. The scope of RIMORPHIS is commensurate with the increasingly complex issues of riverine systems resulting from the multiple competing stresses applied to river environments. Consequently, the platform is being linked to comprehensive multi-disciplinary river morphology resources aligned with contemporary priorities in geoscience research.

Considering the disparities in data collection techniques, formats, storage, and access, one of the objectives of the RIMORPHIS team is to set a general strategy and adequate tactics to engage with the large number of data providers. While there are several examples of successful cross-boundary cooperation for supporting scientific investigations and socio-political decision-making, most of the efforts for assembling the needed geomorphological datasets are fraught with knowledge gaps, potential pitfalls, and problematic developments. Overcoming these obstacles requires closer cooperation between researchers in physical and human sciences and familiarity with the capabilities of the technologies used for documenting coupled human-natural processes. Consequently, the design and assembling of research and education resources for the area of geomorphology, as well as for general water-related studies, can be accomplished not only through intra-disciplinary research but by complementing it with far-reaching learning about interconnected systems, attitude changes, as well as overcoming existing institutional barriers (Cornell et al. 2013).

The objective of this paper is to highlight the RIMORPHIS team's strategy and activities to connect with the earth science and engineering community during the development of the RIMORPHIS platform. Engagement activities to date include the identification of community partners, hosting the two annual project workshops, and one-on-one in-depth discussions with relevant data partners. While some of these activities, specifically, workshops and team discussions, are common to many interdisciplinary projects, the efforts that are involved in undertaking such efforts are rarely documented, thus depriving the community of useful tools and information for broader community engagement. Accordingly, this paper also details the challenges and outcomes of stakeholder engagement and illustrates how these interactions are shaping RIMORPHIS development.

ACTION PLAN FOR SCIENTIFIC COMMUNITY ENGAGEMENT

General Strategy

The design and development of the RIMORPHIS web resources are accomplished with, and for the benefit of, the members of the geomorphologic science and practice communities. For this purpose, our project team aims at shaping, developing, and sharing the final form of the web platform by adopting a participatory approach whereby interested community members are engaged from the project inception and continue to be synergistically involved as collaborators throughout the project's lifetime. Implementation of this collaborative framework cannot be done without giving the community members a sense of belonging, enabling them access to the resources of other communities, and collectively agreeing on specific features to be included in the RIMORPHIS package of software and interactive workflows.

Engaging with scientists and researchers from diverse, multi-institutional science and practice communities within the earth sciences area requires strategies distinct from those geared for engagement with stakeholders or public communities (e.g., Wellcome, 2011). The former type of engagement is more likely of the “in-reach” rather than of the “outreach” nature (CSCCE, 2022). While both scientists and practitioners rely on science and technologies in addressing the complex issues of integrated Earth systems, a strong in-reach engagement is required in co-producing and using comprehensible geomorphic observations in support of decision-making for a wide range of societal areas (Plag et al., 2013). According to Plag et al., the partners’ engagement foci in this area should include: a) improving interoperability between various types of observations, modeling, and information systems; b) facilitating data sharing, archiving, dissemination, and reanalysis; c) optimizing observation datasets, assimilation of data into models, and generation of data products; d) enhancing the value of observations from individual observing systems through their integration; and e) harmonizing well calibrated, highly accurate observations of the same variable recorded by different sensors and different agencies.

Successful engagement of the science and technology community occurs when stringent needs in the decision-making landscape (e.g., legislature, agency missions) require scientific insights to advance the policy dialogue (Smith et al., 2013). If such opportunities do not occur, truthful engagement is hampered by the lack of demonstrable benefits for these communities. There are few models available to inform on strategies for engaging communities of scientists and researchers with the community of practice. One such community-building effort is the Worldwide Hydrobiogeochemistry Observation Network for Dynamic River Systems (WHONDRS, 2022). This community project underpins the mutual value of engagement by promoting open collaboration with a wide variety of stakeholders, enhancing educational activities for the teams and student research assistants, advancing river corridor science through the development of transferable knowledge, and generating open-access data to support publications and proposals. A more generic community-building model is the Community Participation Model created by the Center for Scientific Collaboration and Community Engagement (CSCCE, 2020). This model plays a central role in training Science, Technology, Engineering, and Mathematics (STEM) community managers (CSCCE, 2022) by offering a set of training tools and various related resources (including those promoting diversity, equity, and inclusion principles). Following the conceptual framework, the model is now rolling out case studies co-produced with, and designed for, scientific associations, research collaborations, and organizations that provide scholarly communications infrastructure (CSCCEE, 2022).

A first obstacle in applying CSCEE's, or any other, strategy for building and engaging the community for the development of RIMORPHIS, is that the groups involved in our collaboration pertain to different types of organizations (i.e., academia, industry, federal and state entities monitoring water-related aspects). These groups are distinct through infrastructural organization, mission, and institutional culture. However, many of the CSCCE model's features are common with RIMORPHIS' needs from both strategic and implementation perspectives. Lacking a more suitable framework for community building, the original version of the CSCCE model is deemed suitable as a template for RIMORPHIS efforts (see Figure 1). While the terms used in Figure 1 are quite easy to grasp, the reader is suggested to consult CSCCE (2020) for more details on the model. The structure and the logic of this model encapsulate the steps accomplished so far in the RIMORPHIS engagement strategy for assembling the user community and the same model will fit the needs for guiding the ongoing and future engagement plans.

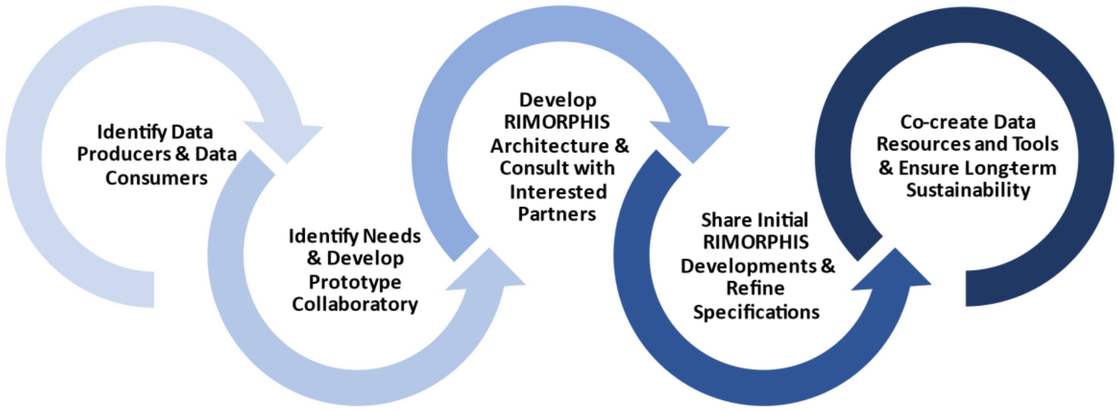

Figure 1. RIMORPHIS community engagement and participation model (adapted from CSCCE, 2020).

To ensure seamless interactions during the engagement with the RIMORPHIS stakeholders, a web-based design is adopted for the communication platform that allows access to multiple resources using web technology (even if they are widely distributed geographically) and displays them in a browser on the user side. In such systems, most of the geomorphological data and information used for investigations remain on legacy systems maintained by the data providers (e.g., Tarboton et al., 2009; Horsburgh, 2010). Similarly, the geospatial and remote sensed datasets can be accessed, processed, and subsequently fed into hydrologic models using web-based tools (e.g., Wang et al., 2011, Ramirez et al., 2022). The most advanced web-based collaborative environments that facilitate multi-user activities is adopted, whereby developed models can be published and run remotely using efficient high-performance computing while the analysis results can be selectively retrieved and visualized for further sharing (e.g., Horak et al., 2008; Rajib et al., 2016; Alabbad et al., 2022). Without relying on any local modeling or computational resources, users with interests in the same geographical area and larger-scope stream morphology problems can use the platform for collaboration even if their end objectives differ from other users in the community.

Implementation Steps

The above-described strategy has been initiated, and continues to follow the path of a plan entailing the steps listed below:

1. *Development of the conceptual architecture and the production process leading to an operational RIMORPHIS* – with the purpose of identifying existing components, producers, and early prototypes that are readily usable in the generic platform for accelerating the overall development.
2. *Identification and engagement with core strategic partners for RIMORPHIS development* – an essential step for the robust development of the conceptual architecture, production process, and business model formulation with the participation of geomorphologic-focused professional communities (e.g., USGS, USACE, USDA) and software producers.
3. Development of *a pilot RIMORPHIS platform* – to provide proof-of-concept tests and allow inferences on further basic research needs. Encourage the utilization of existing academic and industry testbeds that promote transparency and openness to integrate research components suggested by community members.
4. *Setting short-term and long-term development targets backed up by formal collaborative agreements* – for embodying the RIMORPHIS initiative and wide participation from governmental agencies producing and using the data as well as universities interested in Earth Sciences.
5. *Formulating strategy for securing long-term RIMORPHIS development support* – by targeting known funding sources such as NSF Geoinformatics, data collecting and monitoring agencies such as the USGS and USACE, and private entities with interest in stream geomorphology.

6. *Designing an evaluation matrix for RIMORPHIS progress assessment* – for ensuring a measure of sustainable progress of the product development.
7. *Consulting with relevant stakeholders and fostering synergistic collaboration with mission agencies* – for truly engaging with federal, state, and local river-focused agencies in the formulation of RIMORPHIS operational requirements and supporting the implementation of proof-of-concepts to specific testbeds.
8. *Development of a business model for sustained development of RIMORPHIS* – by specifying means for attaining industrial production, commercialization (includes identification of the manufacturers, vendors, and distribution market), and protection of intellectual property aspects.

COMMUNITY ENGAGEMENT ACTIVITIES

Identifying Stakeholders and Community Partners

The identification of community partners was initiated nearly a decade ago even before the inception of RIMORPHIS. During this decade, the stream/river morphology community, similarly to other water-study groups, had been exploring new and efficient methods to organize both historical and newly acquired data. A series of events were organized for this purpose within the stream morphology data-focused groups that included data producers, end-users, and database experts from federal and state governments, academia, non-governmental organizations, and the private sector.

The first such opportunity where some of the RIMORPHIS team members were present was held in 2009 when the Subcommittee on Sedimentation (SOS) of the Advisory Committee on Water Information (http://acwi.gov/sos/) formed a workgroup to assess the possible development of a national stream morphology database. One relevant early realization of the workshop was that no existing database meets all the desired criteria for a stream morphology database without some degree of modification. Relevant databases existed; however, their features and architecture would need to be evaluated for the possible development of a generic platform for the geomorphology community that can support various stakeholder needs. Furthermore, the SOS workgroup explored three primary themes: data exchange scope, data exchange scale and potential data models (Demir and Szczepanek, 2017), and related administrative challenges (Collins et al., 2012). The workshop discussions identified dominant issues for each of the three themes and purposefully recommended the development of a national stream morphology database (SOS, 2011).

A second workshop was held in 2019, under the patronage of the US Geological Survey (USGS) and the US Army Corps of Engineers (USACE). This workshop focused on: i) reviewing past efforts to scope and secure funding for the development of a stream morphology data portal, ii) identifying general data requirements and needs, iii) evaluating existing geospatial platforms, portals, and datasets that could be utilized to provide an initial proof-of-concept; and iv) discussing potential resources and funding opportunities available to develop the proof-of-concept pilot as well as a national program (Wood and Boyd, 2020). A key recommendation from the workshop was to develop a web-based framework that would show locations and types of available data as a short-term incremental goal toward the process of developing a fully functioning portal. Following the 2019 workshop, an interagency team with participants from the USGS and USACE was created to develop a pilot project called the Geomorphology Data Exchange Portal (GDEP). The GDEP project outcomes entailed data visualization and dissemination methods applied to two pilot sites: Cherry Creek in Colorado and the Delaware River Basin (https://rsm-geomorphology-pilot-projects-usace.hub.arcgis.com)

These two major events and follow-up discussions offered abundant opportunities to ascertain who are the major stakeholders and community partners in handling geomorphological data and what infrastructure and developments they pursue. In 2020, the RIMORPHIS project team updated the status of the partners identified over the decade-long interaction and made additional explorations to ensure that new developments in the community are identified. The list of potential partners identified over the reference time is provided in Table 1. Table 1 broadly categorizes the river morphology information system partners as data producers (DP), data system developers (DSD), and data users (DU), as indicated in the Profile column. If one entity performs all these functions, it is labeled as a global data resource (GDR).

Table 1. List of identified stakeholders and community partners.

Entity Name	Lead Agency	Profile
Next Generation Water Observing System (NGWOS)	USGS	GDR
Interagency Geomorphic Data Exchange Portal (GDEP)	USACE	DSD
National Hydrologic Geospatial Fabric (NHGF) Project	USGS	DP, DSD
eHydro – Hydrographic Surveys	USACE	DP, DSD
Cross Section Viewer Tool	USACE	DSD
StreamStats Program	USGS	DSD
National Hydrography Dataset (NHD) and NHDPlus	USGS	DSD
Surface Water and Ocean Topography (SWOT) River Database (SWORD)	NASA	DP
3D Elevation Program (3DEP)	USGS	DP, DSD
Consortium of Universities for the Advancement of Hydrologic Science Inc. (CUAHSI)	NSF	GDR
EarthCube Office	NSF	DP, DSD
Midwest Big Data Hub	NSF	DSD
National Water Center	NOAA	DP, DSD
Internet of Water Coalition	Geoconnex	DU
National Hydrography Infrastructure (NHI)	USGS	DP
National Riparian Areas Base Map	USDA Forest Service	DP
Earthchem and System for Earth Sample Registration (SESAR) + B32	Columbia University	DSD

Entity Name	Lead Agency	Profile
Reclamation Information Sharing Environment (RISE)	USBR	DP, DSD

Screening of RIMORPHIS Relevant Stakeholders and Community Partners

One of the most important criteria for an effort targeting a wide audience such as the earth science and engineering community is to access data producers with sizable and diverse data covering large areas, ideally nationwide. Another important criterion for boldly initiating such an effort is to judiciously choose the number and profile of the first partners engaged in the collaboration. These two selection criteria were primarily accomplished by: a) assembling a synthesis of the essential features of the data sources produced by the identified partners; b) contacting the partners' leadership for requesting additional information that was not publicly available, and c) setting the collaboration arrangements. Given the circumstances surrounding the COVID pandemic, most of the interactions during the screening phase were made through virtual meetings set individually with the initial partners. These meetings further garnered details on data scope and extent, format, archival protocols, and availability of Application Programming Interfaces (API).

Initially, three data partners were screened for collaboration in developing the RIMORPHIS platform: USACE eHydro, USGS 3D Elevation Program (3DEP), and the USGS-USACE led Interagency Geomorphic Data Exchange Portal (GDEP). The USACE eHydro system provides access to hydrographic surveys that have been collected primarily in large rivers used for navigation purposes (https://navigation.usace.army.mil/Survey/Hydro). The USGS 3DEP online portal provides access to nationwide elevation data including aerial lidar point clouds and digital elevation models (https://www.usgs.gov/3d-elevation-program). The Interagency GDEP is a searchable, georeferenced online tool that provides access to geomorphic and bathymetric data in a variety of formats. A more recent collaboration includes the USGS's National Hydrologic Geospatial Fabric (NHGF) project team that compiles and makes available through internet hydrographic datasets of geospatial data for hydrologic simulation modeling (https://www.usgs.gov/data/geospatial-fabric-national-hydrologic-modeling-version-11).

Annual RIMORPHIS Workshops

Two annual virtual workshops were held to engage the broader groups of stakeholders who may benefit from RIMORPHIS. Both workshops were delivered with identical structures, presentation modes, and targeted results. The first workshop, held in May of 2021, had participation from 63 individuals representing 16 universities, 7 government agencies, and 4 other industry entities. The second workshop, held in May of 2022, had participation from 150 individuals representing 54 universities, 7 government agencies, and 37 other industry entities. The workshop materials are available in their entirety on the RIMORPHIS website (rimorphis.org). The essential elements of the engagement process and key outcomes are detailed below.

The primary workshops objectives were to: 1) inform participants on the design and development of the platform; 2) seek partnerships for sharing data resources; 3) survey participant expectations and feedback on the platform's functional and operational features; and 4) seek collaboration on all aspects of RIMORPHIS development. A visual overview of the RIMORPHIS Workshop mechanics is shown in Figure 2. For the first workshop, the key elements included pre-workshop surveys, an overview presentation of the RIMORPHIS vision, lightning talks from key stakeholders, moderated discussions, and post-workshop feedback.

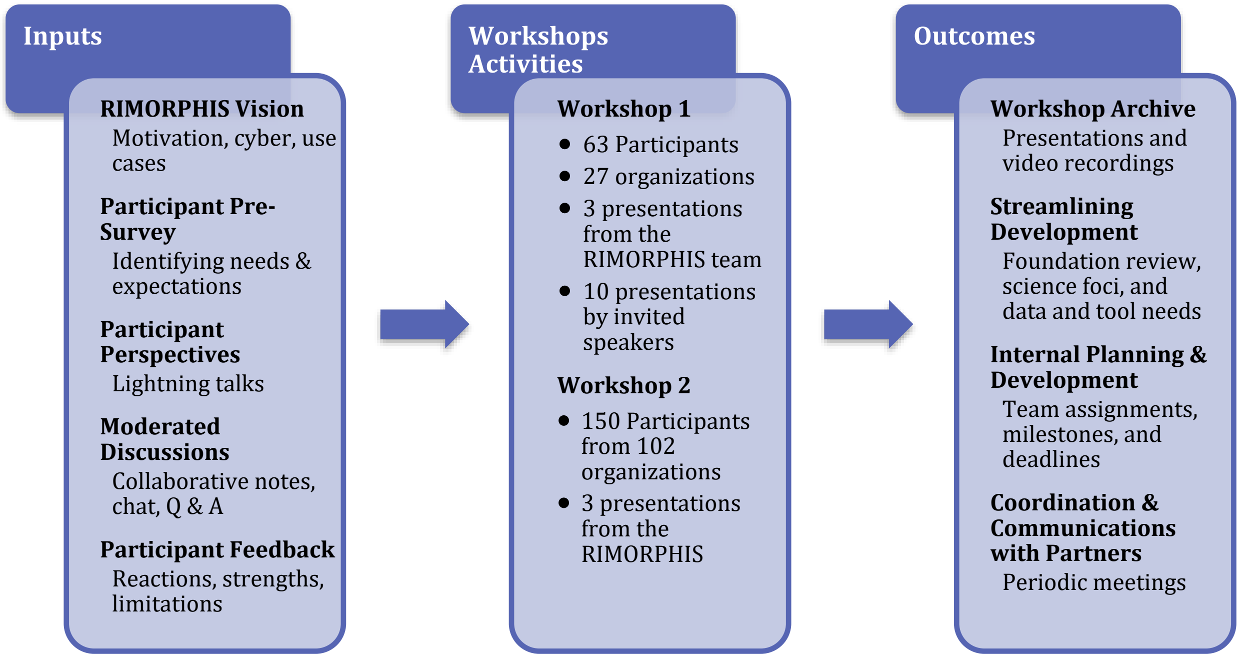

Figure 2. Overview of 2021 RIMORPHIS workshop mechanics including inputs, workshop activities, and outcomes.

Receiving input from each of the stakeholder types (i.e., data collector, storer, and/or end-user) is critical for the successful development of the RIMORPHIS platform. Input was solicited regarding preferred data types, functional features, and analytical tools to be included in the RIMORPHIS platform as well as partnerships for data sharing. The primary methods employed to obtain stakeholder input included pre-workshop surveys, lightning talks from potential data partners, and workshop breakout discussion groups. Figure 3 provides a synthesis of input from participants regarding their river morphology data activity including primary data of interest (e.g., cross-section surveys, free-surface and bed profiles, and reach-scale bathymetry), most often-used data (e.g., water surface elevations and extents, topographic data, and remote-sensed/airborne data), most often-used data collection instrumentation (e.g., lidar, topographic survey, and single-beam echosounder), and primary data storage methods (e.g., dedicated servers, individual hard drives, and online cloud systems).

Data of Interest

- Cross-section surveys
- Free-surface/bed profile
- Reach-scale bathymetry
- Stage
- Flow discharge
- Topography
- Hydrography
- Streamflow statistics
- Bathymetry/cross sections
- Aerial imagery
- Watershed/land use characteristics

Variable of Interest

- Flow discharge
- Cross-section surveys
- Floodplain DEM
- Reach-scale bathymetry
- High-resolution lidar topography
- Bathymetry
- River characteristics
- Hydraulic geometry

Relevant Datasets

- Channel geometry (NHDPlus, HYDRoSWOT, HydroSHEDS, GRWL, MERIT, NWIS)
- Water surface elevation & extent
- Topographic data (OpenTopography)
- Remote sensed/airborne imagery (3DEP)

Features of Interest

- Ability to create new centerlines and edge of water/data
- Ability to incorporate dynamic hydrology
- Interoperability with other hydro systems
- Ability to push edits to other efforts (NHI, HydroShare, NGHF)
- Group data & tools around grand river morphology challenges
- Incorporate FEMA data

Commonly Used Data

- Water surface elevation & extent
- Topographic data
- Remote sensed/airborne imagery

Common Instruments

- Lidar
- Topographic surveys
- Single-beam echosounder
- ADCP
- Multi-beam echosounder
- Radar

Data Storage

- Dedicated server
- Individual hard drive
- Online cloud system

Tools of Interest

- Link river features longitudinally
- Sediment budgets (total/trends)
- Services to share
- Collation of open-source software

Figure 3. Participant input regarding stakeholder river morphology data activities including types of data, data collection instruments, relevant datasets, data storage, variables of interest, and tools and features of interest.

The various engagement activities were also used for identifying key river morphology variables of interest and the preferred tools and features that could be incorporated into RIMORPHIS. A summary of participant input regarding variables of interest, preferred tools, and platform features is provided in Figure 3. The variables of interest were primarily related to bathymetry and key features discussed included accessing raw data, visualizing multi-datasets, and converting data formats. Participants identified sediment budget analysis, and historical and predictive analysis as tools they would envision to be available in the RIMORPHIS platform. The synthesis of the workshop outcomes and the decision on the next steps were subsequently developed with results illustrated in Figure 4.

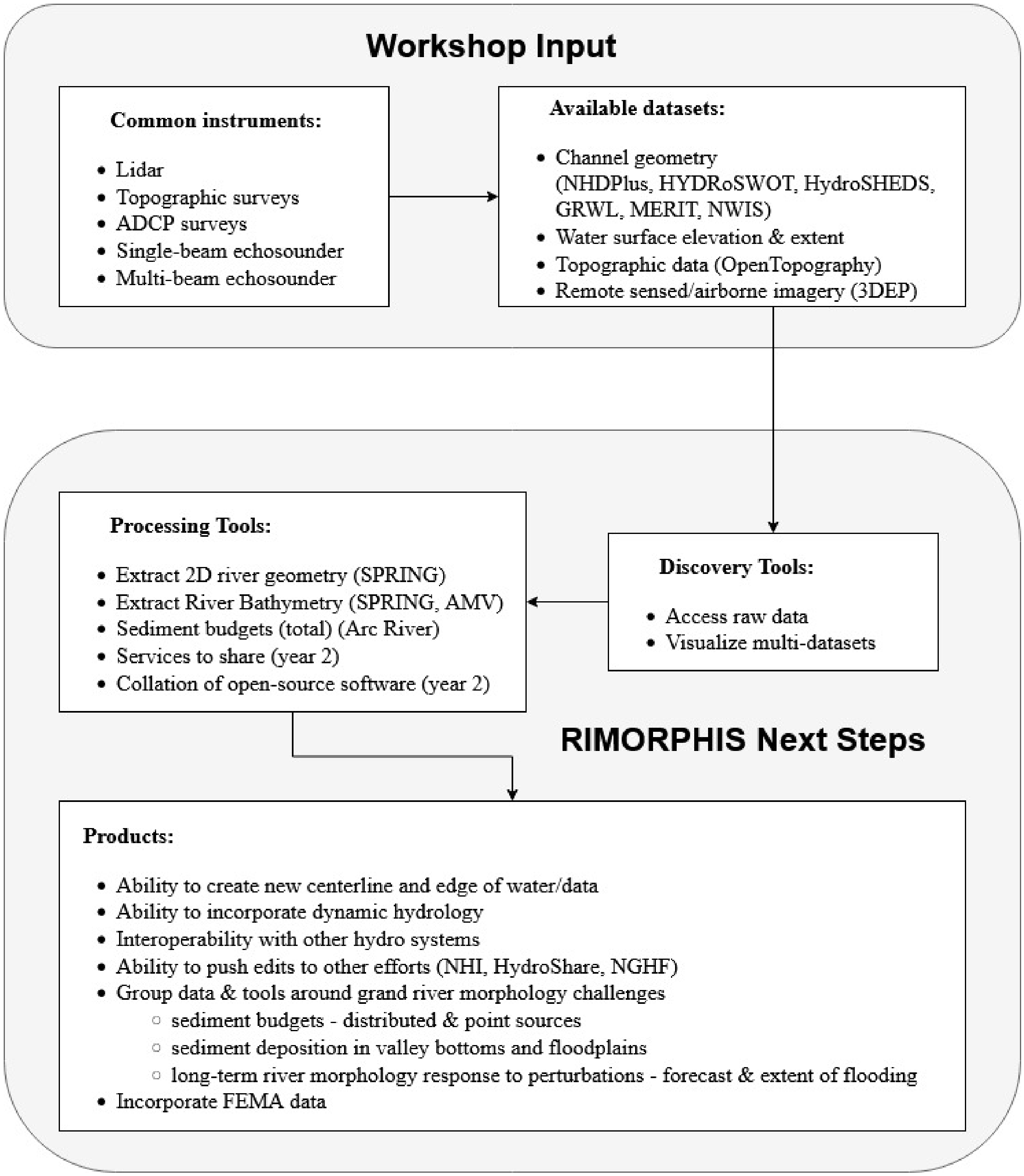

Figure 4. Synthesis of the 2021 workshop inferences including common instruments, available datasets, discovery tools, processing tools, and end products.

Regular Engagement Interactions

Several complementary activities were conducted in addition to the annual workshops. One-on-one virtual meetings with the selected data partners (3DEP, eHydro, GDEP, HydroShare, and NHGF) and the RIMORPHIS team were held to discuss how their datasets could be integrated into RIMORPHIS and what tools are beneficial for our immediate collaborators. Also, presentations were made at several conferences to broadly disseminate the RIMORPHIS activities with the larger Earth sciences community and solicit additional feedback. The attended conferences include the American Geophysical Union (AGU) meeting, AWRA Geospatial Water Technology Conference, UCOWR/NIWR Annual Water Resources Conference, and the Sedimentation and Hydrologic Modeling (SEDHYD) Conference. Besides the traditional conference oral and poster presentations, other avenues were used to have close interactions with stakeholders and partners. Specifically, the 2022 AGU Fall Meeting entailed a Town Hall and Workshops, where a suite of RIMORPHIS-focused dissemination and brainstorming activities were conducted. This suite of activities has brought essential reflections and suggestions on how to better streamline the RIMORPHIS platform for addressing the geomorphologic-related needs of the wider scientific community. The routine engagement also entailed presentations of the RIMORPHIS platform at the four institutions of the team partners with the double role to disseminate the project progress and to recruit new students in the team.

ADVANCEMENTS AND DIFFICULTIES

As follows from the above discussion, a wide collaborative effort is required to advance the RIMORPHIS vision. The breadth and depth of the RIMORPHIS vision extend well beyond the reach of a single research and development group. It requires the integration of capabilities and efforts on a national scale and a long-term commitment. So far, the engagement efforts have been related to the assimilation of cyberinfrastructure that can: a) streamline massive amounts of information across geographic and institutional boundaries using interoperable systems and tools; b) integrate high-resolution information products using service-oriented architecture; and c) engage stakeholders in co-producing the final form of the web-platform.

The initial project outcomes were well received within the geomorphic community and stirred interest from other areas of science that are supported by geomorphology. All the aforementioned achievements could not have been attained without engagement efforts. Among the activities undertaken, the most impactful engagement activities conducted so far are the first two all-hands annual RIMORPHIS s workshops. The number of participants, level of engagement, and commitment toward collaborative efforts were substantially increased from the first to the second workshop resulting in a multi-institutional alliance of core partners that is in continuous contact at this time. The core partner interactions were always mutually beneficial with expressed interest in the harmonization of future developments to make the individual development efforts complementary and interoperable. The joint strategy of the core partners includes concrete steps toward setting the path for the assimilation of the necessary technologies, data, and information to create a generalized, web-based platform for geomorphological studies that can be quickly set into practice.

Attaining the project outcomes highlighted above took considerable efforts focused strictly on engagement compared with the annual workshops originally planned for the project. Obviously, these unplanned efforts came at the expense of other potential developments that at this time remain in the planning phase. However, efforts that lead to attracting partners are deemed critical for setting longer-term goals and assigning the engagement as a success rather than a backlog. Based on the positive impact garnered so far, attracting and engaging current and new partners is a priority. Being mostly a team of engineers, it is difficult to develop a solid plan and a business model for eventually converting RIMORPHIS into a self-sustained community resource. Issues such as specifications on the governance model for RIMORPHIS, attraction of industrial partners for attaining industrial-grade performance, and solving the intellectual property issues are beyond RIMMORPHIS team members' expertise and professional background and will need even more collaborations. For this purpose, future engagement efforts will seek synergistic collaborations with mission agencies that have the potential to accelerate the platform maturation, demonstration, and transition to practice. Fortunately, The National Science Foundation is currently initiating a bold program to build an integrated data and knowledge infrastructure (NSF, 2023) that is squarely aligned with the multi-agency translational research envisioned for our future engagement efforts.

CONCLUSIONS

A multi-university collaborative effort is being conducted to develop an online platform for river morphology data with the goal of making data more accessible and more useful by providing data in convenient formats with tools and features to help visualize and analyze these spatially and temporally complex datasets. The Earth Science community is the primary targeted beneficiary of the full-fledged RIMOPRPHIS data and information platform. However, given that most of the organizations that collect, store, and utilize river morphology data to be integrated into the RIMORPHIS platform are produced by governmental and private organizations, they are considered potential partners both as data providers and users of the assembled project products. Consequently, a key factor for the success of RIMORPHIS is to create a meaningful engagement with a stakeholder group including disparate entities including academic, governmental, and private organizations with varying interests and needs pertaining to river morphology data.

The adopted approach for community-building started with identifying stakeholders and stakeholder needs, developing the prototype platform for collaboration, and consulting and cocreating a sustainable path for future platform growth. For translating RIMORPHIS from vision to practice, developments were driven by inputs from specific engagement activities in a phased sequence that include: a) developing the initial conceptual architecture and the production process; b) hosting annual workshops to continuously solicit feedback from scientific and practice geomorphologic community partners; c) identifying and interacting with core strategic partners; d) delivering a pilot RIMORPHIS platform; and e) disseminating the project efforts and solicit feedback at national conferences. The initial engagement efforts have created a robust foundation for continuing the collaborative work with interested partners and ultimately co-create effective resources and tools that will benefit the whole geomorphologic community. It is expected that by pursuing a constructive engagement agenda, the development of RIMORPHIS will move from the prototype phase to a readily implementable resource in multi-institutional settings and eventually to a widely adopted community asset that will be self-sustainable into the future.

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