Surface and Ground water hydrology

What is hydrology

Hydrology is the study of water and the water cycle, focusing on surface water and groundwater on land. A hydrologist studies the hydrologic cycle, how water interacts with the environment including how it moves from the earth's surface 1. This includes understanding the natural movement of water, but also the human impact on water resources and water quality. It's important that we fully understand the hydrologic cycle because so many industries are reliant upon sustainable, clean water supply.

GIS to solve the challenges in hydrology

It is broadly considered that there are three main challenges in hydrology:

pollution mitigation and quantification in groundwater and surface water supplies

identifying and managing sustainable water use

Improved flood management.

Powerful GIS modelling is able to overcome many of the challenges we see in hydrology, by combining multiple datasets and simulating hydrological processes. With global challenges like population increase and climate change, GIS has the ability to process large datasets and accurately model hydrological processes. In addition, remote sensing technologies include ground-based remote sensing instruments, airborne platforms (e.g. LiDAR), satellite systems and sensors are highly beneficial to hydrological data collection. Large scale satellite imagery like Landsat and Sentinel-2 provide medium to high spatial resolution imagery of land and coastal areas 3. Gadgets like flow gauges, GPS equipped sonar boats and remotely managed weather stations are becoming vastly cheaper and easier to access at the same time 4. The best thing is, that so much of this data is freely available which only goes to boost its effectiveness in hydrology.

GIS in surface water monitoring and management

How surface water collection occurs is important to understand, so we can identify patterns of flooding and flood risk, the impacts it has on infrastructure and how climate change will influence hydrological systems. Understanding and mapping surface water movement over large areas have been difficult until GIS came into frame 5. There are different levels of surface water maps, those that display at a large scale and show bodies of water both man-made and natural, and then there are urban surface water maps which are heavily influenced by infrastructure and impervious surfaces which can make them more challenging to develop. Flood-related damage in the summer of 2007 in the UK in urban areas was caused primarily by surface water flooding, for which no models, forecasts, warnings, or management strategies existed 6. Many governments and authorities around the world have created catchment scale and urban surface water maps that are able to be viewed and downloaded by the public, so this valuable information is available to everyone.

Large scale surface water mapping

To produce large-scale surface water maps, satellite imagery has been particularly useful. There are two main satellite systems, Landsat and Sentinel, and they have new models launched every few years. The two satellite systems vary in different ways, but both provide multispectral imagery of the Earth's surface, which can be used to identify the presence of vegetation or water bodies and carry out hydrological modelling 6. Catchment modelling takes into account other variables such as rainfall, evaporation, soil type and elevation have on the amount of water runoff. These rainfall-runoff or watershed models use a comparison of observed runoff against the computer-generated runoff simulation 6.

Urban surface water mapping

In comparison to rural areas and catchment mapping, urban areas have more complex and irregular topography with buildings, drainage networks, and other infrastructure that has to be factored in 6. Relatively rapid improvements in GIS and hydrological modeling have made it possible to map urban surface water with a high degree of accuracy. However, it's essential to have good quality drainage network maps, as the severity of urban surface water flooding is often highly dependent on the capacity of drainage systems 6.

GIS in groundwater monitoring and management

Groundwater is the most extracted material and provides almost half of all drinking water to the worlds' population 7. As with any non-renewable natural resource, groundwater needs to be monitored and managed to protect it from contamination and overuse. Groundwater supplies are used by agriculture, industry and for urban use. Primarily groundwater is used in agriculture, but also to support industry and manufacturing and for drinking water in cities 7. GIS gives hydrologists and land managers the ability to predict the movement of contaminated water, monitor available groundwater, predict groundwater supply, estimate sustainable abstraction potential and conduct future groundwater development planning 7. Without adequate groundwater management, overuse could lead to a declining water table and water scarcity that has big impacts on communities, industry and agriculture who are often heavily reliant on it. GIS can be applied successfully to manage and monitor groundwater resources. It’s possible to use GIS and remote sensing to identify water fluctuations and patterns, detect aquifer recharge zones, assess and classify periods of hydrological drought, identify vulnerable aquifers, and map areas with viable groundwater 7.

GIS to map groundwater potential

It’s possible to use a combination of GIS layers to map areas likely to have a high potential of suitable groundwater. In India, GIS layers like ground cover, Normalized Difference Vegetation Index (NDVI), and slope (DEM) are used as a first step to identifying area with possible groundwater reservoirs in the desert of Rajasthan. Computer-generated maps can then combine all this data to indicate areas with a low to high potential for groundwater reserves. This means land managers can place wells or bores in the most optimal locations, but this groundwater still needs to be monitored in order to be used sustainably.

GIS to monitor groundwater

Most commonly, static monitoring stations are used to relay data like height levels and water quality information back to a database. In the United States, the National Groundwater Monitoring Network (NGWMN) have an extensive system of real-time gauges monitor groundwater levels to over 14,000 wells across the country 9. These gauges are also able to send back data on water quality as well, enabling managers to understand the overall health of the groundwater at that site. Australia also has a network of over 900,000 groundwater monitoring sites with data provided via an open-source website, the Australian Groundwater Explorer 10. This kind of collaborative, open-source data sets are invaluable across jurisdiction boundaries. In places where logistical issues pose a great challenge to scientists and land managers, it's possible to use GIS models to predict groundwater levels based on recharge rates from satellite imagery 11. India is undeniably the world leader in groundwater use. The country has a rapidly growing population but, a limited fresh water supply 12. This has led to a range of community-based groundwater management and water budgeting programs. In situations where data collection has been more challenging to complete, technology is making accurate and efficient data collection a reality. A free and open-source GIS application called 'Jaltol' has been launched. It is preloaded with rainfall data, soil moisture storage data, evapotranspiration data, groundwater storage data and land use maps, all from various reliable sources 13. Farmers and villagers now have the tools to monitor and manage their groundwater use.

GIS to monitor the world's largest artesian basin

The Great Artesian Basin in Australia is another example of GIS enabling better monitoring and management of groundwater reserves. In 1878, Australian settlers began tapping into this water resource and gradually expanded the network of bores across the land. This network of bores grew to around 50,000 and most of them were allowed to flow freely to water livestock. This caused a noticeable drop in pressure and raised concern in the early 1900's about unsustainable use of the resource 14. The basin has areas with natural springs and vents that flow up to the earth's surface from certain points across the landscape. These provide important ecosystem services to the arid landscape and a better understanding of these spring locations, character and status would help the overall hydrological management and recovery of the Basin 15. From 2008-to 2012 a project was run to assess the use of advanced survey and remote sensing technologies for monitoring the overall health of the spring wetland systems. Part of the project involved mapping flowing and extinct spring vents to establish a baseline record of spring activity status for future water allocations 15. Without this baseline information, it would be impossible to accurately monitor the impacts of groundwater use in the future. Due to large distances to cover the team utilized a Differential GPS for the highest accuracy and rugged water meters for measuring pH, conductivity, temperature, and dissolved oxygen 15. A multi-million dollar project to investigate the infiltration and storage of water in the basin using supercomputers and satellite technology will conclude in mid-2022 15. This investment and use of GIS technology is contributing to the successful management and recovery of the Great Artesian Basin.

Future of GIS in hydrology

As the world we live in changes so too does the technology we use need to adapt in order to effectively monitor the hydrological cycle. Cross-disciplinary sharing of data and information from the atmosphere, hydrosphere, lithosphere, and biosphere is essential. Our modeling and predictions are only as good as the data we input and continually improving GIS software and remote sensing technology facilitates the development of numerous cheap and useful sensors and survey techniques 17. This offers significant opportunities to improve our analyses and predictions through data-model fusion, real-time learning, and recursive forecasting into the future