

MANAGING DAM HAZARD IN CHANGING URBAN SPACES

Dam owners and regulators must be constantly vigilant for the creeping hazard of a changing urban landscape.

With downstream housing and commercial development increasing the demands on inspections and resources constrained, regulators are turning to new digital tools to help them reduce risks and keep people safe.

For dam owners and the regulatory agencies responsible for ensuring dam safety, risk isn't a static problem but rather a dynamic challenge that must be regularly assessed as conditions change. So-called hazard creep can occur for a number of reasons, such as climate change or aging assets for example. However, hazards can also evolve over much shorter time scales.

One of the most significant issues facing dam owners and regulators in managing hazard creep is urban development. As the global population expands and homes and commercial spaces are developed in once-rural areas, new communities can start to encroach downstream of hydraulic structures and within floodplains or inundation zones. As Association of State Dam Safety Officials (ASDSO) President Bill McCormick notes: "Generally there is much more urbanization. That's certainly an issue and I think it's pretty common across the US."

New buildings can spring up quickly and where these appear in the inundation area of a dam this may have a major impact on the hazard classification of such a structure. Indeed, the latest Infrastructure Report Card from the American Society of Civil Engineers notes that over the last 20 years the number of high hazard dams



has more than doubled across the USA as development encroaches on dams and reservoirs that were once rural but now feature downstream construction.

Changing dam hazard classification

Dams are broadly categorised as low hazard, a significant hazard or high hazard depending on their size and hazard potential, such as the risk of loss of life in the event of a failure. The management regime associated with these classifications is radically different.

"Whereas previously, a dam could overtop and fail and the damages would be minimal. With risk to human life the owners have to invest in more protection for their dam which can be very costly.

Then there's certainly a heightened monitoring and surveillance requirement for high hazard dams with more frequent inspections or installation of monitoring instrumentation to keep a closer eye on things," says McCormick.

An inspection of a low hazard structure is required only once every five or six years whereas for high hazard structures the requirement is for an annual inspection and owners must also develop and share an emergency action plan (EAP).

In the USA these plans are mandated by State Dam Safety programs and the Federal Energy Regulatory Commission (FERC) among others and formally detail potential emergency conditions at high and significant hazard dams. EAP's also



detail specific pre-planned actions that are to be followed in the event of an emergency. They are designed to minimise damage to property and any loss of life. The EAP also contains procedures to assist the dam owner in issuing early warning and notification messages to downstream emergency management authorities as well as inundation maps to show the critical areas for action in case of an emergency.

Of the more than 91,000 dams in the USA, around 15,600 are currently classified as high-hazard structures. The number of high-hazard-potential dams has increased as has the overall percentage

of these dams with an EAP. As of 2018, 81% of the country's high hazard dams had a plan on file, a 5% increase from the 2015 figure according to the ASDSO. In addition, for high hazard structures, owners usually invest more on producing flood maps and recording inundation zones, while for low hazard dams this assessment is often a more ad hoc approach as the potential consequences are much smaller.

Nonetheless, in order to ensure dams are appropriately classified and that any necessary EAPs are in place some states require dam owners to self-report changes. In most states regulatory bodies are required to keep abreast of urban developments and any new houses or commercial buildings that have been constructed downstream of a dam and in a potential inundation zone. A critical step in the periodic inspection of low and significant hazard dams a review of new downstream development. When inspectors visit dams they also strive to identify any new structures or dwellings that could increase the consequences of failure, and therefore the hazard classification.

Walking the walk

Historically, this assessment of urban development has been conducted by the regulatory inspectors who are responsible for assessing dam conditions and safety. State Dam Safety Programs hold regulatory authority over nearly 70% of all the 91,000 dams listed in the USA and are responsible for inspecting existing dams, overseeing remediation of deficient dams, and working with local officials and dam owners on emergency preparedness. Changes to dam classifications are assessed through physical inspections and by experts walking an inundation zone to determine if hazard conditions have changed.

However, this potentially represents a knowledge gap for both dam owners and regulators. "There's no formal notification process that somebody has

built a house and they have to tell the dam owner or the regulator that that's what they've done," says McCormick.

This is a point echoed by Phoebe Percell-Taureau, Chief of Dam and Levee Safety at the US Army Corp of Engineers (USACE), who says: "We rely on states and local communities to be the flood plain managers and those local communities may choose to allow development in that area even though they can be inundated by the operation or failure of our dams. That's where there can sometimes be a disconnect between what we're doing as a federal government body and the facility owner and the state and local community choices downstream of a dam."

Even so, regulators are heavily engaged in looking for potential hazard creep. "We rely on our field officers that are responsible for the operation and maintenance of those facilities to pay attention to what's going on down stream and we do a pretty good job of that," says Percell-Taureau.

"Our engineers are regional so they cover a certain territory and they get to know that territory so they get a feel for when changes are happening and where a dam might be impacted by development downstream," notes McCormick, adding: "Sometimes we have dams that might be in close proximity to others that are inspected on a different cycle and so an engineer could just be driving in the area and recognize that the hazard classification for a dam not due for inspection for a couple years has changed. We can take proactive steps like that."

Simultaneously though, many state programs lack adequate budgets and staff. According to the ASDSO, in 2019 the average state dam safety budget for each high hazard potential regulated dam was less than \$5,000 annually. Furthermore, with less than 500 state dam safety staff nationwide in the USA, available monitoring

assets and in-field experts are necessarily spread thinly on the ground. They're mitigating the circumstances as best they can, but that clearly leaves a potential public safety risk.

Dam owners and regulators often operate across vast geographical areas and with urban change effecting rapid change, the chances of a new housing development, community or commercial building arriving within a dam inundation area between inspections is increasing. Growth in urbanisation is itself placing additional requirements on regulatory bodies too, exacerbating the problem. "Our program in Colorado probably has had anywhere from five to eight hazard classification changes a year over the last 10 years so we've added about 80 high hazard dams due to this hazard creep issue. This impacts our workload for dam safety programs because instead of looking at a dam and doing work every six years for a low hazard dam we have to do those same kinds of activities every year," says McCormick.



Old job, new tools

Given the growing demand for inspections, the increasing pace of urbanisation and the challenge of budgetary constraints, regulators and dam safety officials are now exploring new digital tools that can support their operational needs. They are adopting these measures in a bid to ensure all

dams are classified correctly and that they have the appropriate safety measures in place.

Some are already using open access satellite observations such as Google Earth or Digital Globe to support their physical observations. “We use tools like GIS where we can import the national infrastructure inventory and look at how that may intersect with the inundation boundaries of our facilities and also census data so that we can understand how populations are growing within our inundation reach. Satellite data is one of the layers that we can turn on in our GIS system,” says Percell-Taureau.

Open access mapping tools are thus being scrutinised by regulatory staff to try to identify potential changes remotely. As McCormick explains: “That’s just using the tools that we have available to us. Back in the day you had to drive around more, but now you can maybe spot something from a distance and then go back to the office and pull it up on Google Earth and see what’s going on. Once you see something on Google Earth then you can do the field work to see if it really is a problem or not and then do some modelling to double check it.”



There are limitations to this approach though. Google Earth provides the date of the imagery being viewed at any given time and in addition has historic imagery, so you can look back and see when development might have occurred. However, in some areas the most recent imagery might be

two to three years old, which is a constraint for real-time work.

It is also possible to view observations in which tiles on the same page are not contemporaneous and therefore miss substantial urban developments in an inundation zone that could have a significant bearing on the hazard rating of a dam or other hydraulic structure. Indeed, in some images of the area around a dam, zooming in to the map presents older images and so houses can disappear as observers attempt to get a better view.

To minimise dam risk in the age of hazard creep it is clearly important to have a reliable quality data set to review urban change and new tools are now becoming available that can fill this gap. One such development comes from geospatial AI firm Rezatec.

Mapping change with machine learning

Rezatec’s Downstream Hazard tool gathers high-resolution optical data from satellites and a subsequent analysis using their machine-learning algorithm to identify new dwellings or commercial buildings within an inundation or flood zone. The AI algorithms are used to assess and identify data clusters that look like a house, using machine learning to understand local building materials for example.

The learning is based on the buildings in the surrounding area and the algorithm also rules out things like bodies of water and other extraneous data. Analysis of visual satellite data from two different time periods allows new buildings to be detected. The flood zone or inundation area is overlaid onto the map and having identified a potential structure at risk the tool flags that location for further investigation. Presented with a timely update on structures that potentially affect a dam’s hazard rating without having to wade through all the data, dam safety officers are able to proactively prioritize dams with potentially risky new urban

developments in the flood plain.

Using freely available data keeps the costs down and does offer far more frequent observations than every five or six years. It therefore narrows the window of potentially dangerous uncertainty. "The data gives a very comprehensive set of high-resolution optical data to get that detail of a house. It means that for a dam considered low hazard we're getting several additional views of that dam that wouldn't have occurred under a normal regime of physical observations," says Camilla Braithwaite, Rezatec's Head of Product.

With dam owners and regulators able to identify changes in urban development much more easily than with infrequent, manual inspections that can take weeks or months to complete, the Downstream Hazard tool is able to provide a central view of changes within the inundation zone of every dam across a whole state. Highlighting potential changes to risks and hazard classifications is a targeted resource approach that allows regulators to deploy their staff resources with maximum efficiency.

"These kinds of satellite observations really help with ensuring dams are appropriately classified in a timely way and that their emergency action plans are in place and up to date," says Braithwaite.

With dam safety officers able to prioritize dams where change has occurred, it may be possible to reduce resources expended on other dams that aren't such a high priority because nothing has changed over the course of several years. Remote observations can also potentially improve workplace safety. For example, when sending people out to walk the flood area and perhaps explore steep-sided ravines to check for new houses or commercial buildings there is the possibility of trips and falls or encountering wildlife, such as venomous snakes.

"Having some tools to go beyond our normal drive arounds would be certainly helpful, something automated. It is an interesting idea to use more satellite and AI technology to know if there a new house below this dam since the last time we looked," says McCormick.

Braithwaite reports that technology companies are able to develop new products and spread the costs across the industry: "With most regulators struggling for resources, we want to drive efficiency with our technology. Rather than each regulator developing their own solution we can provide a lower-cost alternative," she says.

Keeping people safe in a changing world

With a mandate to protect public safety and prevent economic loss from potential dam failure, and faced with a rise in urban development, dam safety officers are evidently challenged by a lack of resources even as their role has never been more important.

Traditional methods of ground survey and inspection are often too resource-intensive to keep up with the rise in urban development in the inundation zones of the dams they are responsible for and potentially risky urban changes can therefore occur between inspections. New buildings and hazards can go unrecorded and unactioned which can impact hazard classifications for longer than is ideal.

Dam owners and regulators now have alternative options when it comes to monitoring structures and surrounding areas. Using data from space rather than relying solely on ground-based inspections, clever machine-led analysis can enhance their processes and make sure new communities are identified before any potential failure puts them at risk.

"In terms of the regulatory workload it's not necessarily going to mean they've got less to do

but it can help better prioritise their time more effectively, so they are able to keep ahead of their regulatory obligations and keep people safe," says Braithwaite, adding: "These kinds of satellite observations help ensure dams are appropriately classified in a timely way and that their emergency action plans are in place and up to date."

As McCormick concludes: "It would be a good if we could use those tools because certainly the problem is that we have a limited number of staff to address these issues of changing hazard classifications. I think these kinds of tools would at least let you know if there are any blind spots out there and risks that need to be managed to some acceptable level."

Regulators can't prevent change, but with smarter tools it is possible to keep people safe in the most productive way.