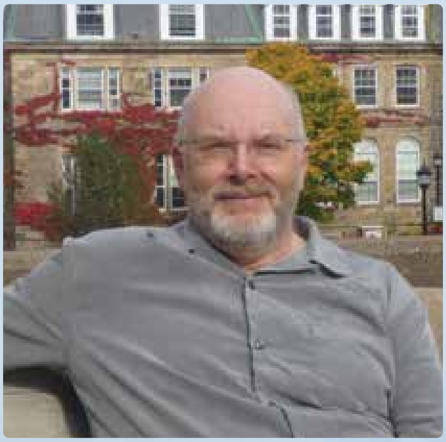
Beyond the watershed

Dr Paul Arp provides insight about a new method for modelling and mapping soil wetness across landscapes, and details some of the many practical applications that arise from this innovation

DR PAUL ARP



What are the key goals of your most recent projects dealing with wet areas and soil trafficability mapping?

We are interested in providing and developing high-resolution soil wetness models through our research. The resulting maps, which detail slope, flow direction, stream channels, and wet areas across the land are useful in a variety of applications. This includes the planning of land use operations in forestry, parks and agriculture, storm-water management, and inland and coastal flood risk assessments. The wet-area maps are also of importance for detailing natural habitats and vegetation patterns across landscapes, and for generating daily to weekly soil trafficability forecasts, to reduce machine-induced soil disturbances, by weather and season.

Can you discuss what makes the Forest Watershed Research Centre particularly well placed to conduct work in this area?

The Forest Watershed Research Centre, being part of the Faculty of Forestry and Environmental Management at the University of New Brunswick (UNB), builds on established and continuing partnerships with industries, federal, provincial and municipal governments, and others. These partnerships are dedicated to the application and communication of watershed research in order to develop and promote sustainable and integrated forest management policies and practices. This Centre specialises in its research on primary land resource conditions pertaining to soil, water, nutrients and biomass, as well as related flows through forested watersheds and streams, summer through winter.

Further to this, could you discuss some of the main achievements of the Centre itself?

Among the Centre's technical achievements have not only been the development of wet areas mapping algorithms, but also the verification of the resulting maps for specific purposes. We have mapped flow channels

The lay of the land

Where land and soils dry and remain wet dictates, to a large degree, how landscapes function from day to day and through the years; now the Forest Watershed Research Centre at the Faculty of Forestry and Environmental Management, **University of New Brunswick** in Canada has developed a solution that is changing how forest managers and other land users are planning and conducting their field operations

WHILE MUCH EMPHASIS has been placed in developing proper soil management and conservation techniques, navigating across landscapes based on metre-by-metre changes in soil dryness and wetness has not been feasible until now. The breakthrough has come through the increased availability of high-resolution digital elevation models (DEMs) for bare-earth surfaces. These DEMs are now enabling the recognition and mapping of continuous soil wetness changes across landscapes from ridge tops to valleys. For example, off-road traffic on soils when wet can have severe impacts on soil quality in terms of soil compaction, rutting, displacement, water and wind erosion, flooding, and slope stabilities, thereby making soils less suitable for intended purposes, eg. crop production.

Using land resources as well as soils efficiently, safely and sustainably is now of anyone's interest, and especially so within the context of conflicting uses, as these can range from industrial, agricultural, residential and recreational, and from private to public. The problem is knowing where and when soils are wet, moist or dry, how they drain, and where they drain to.

SUPERSEDING THE SURVEY

Until recently, the best way to acquire high resolution soil wetness information was to conduct ground-based surveys – but doing so has many drawbacks. Firstly, intense soil wetness surveying is hugely limited when dealing with large areas; one surveyor, or even a team of surveyors, can only cover so much ground in a set period and wet areas at a resolution of one metre for large areas in New Brunswick, Alberta, Ontario, Maine and Sweden. At 10 m resolution, we have mapped entire provinces such as New Brunswick and Nova Scotia, states such as Maine, Vermont and Hawaii, and even whole countries like Belize, Bermudas and Haiti. Our mapping also extends to parts in Uruguay, Germany, Hungary, Venezuela, Chile, South Africa, Malawi, Tanzania, Mexico and Malaysia.

What kinds of uses can these maps be put to? Do they require further research in order to be of practical value?

Another part of our work involves adding ecological and managerial interpretations to the maps, by detailing soil properties (type, drainage, wetness), habitat (by drainage and vegetation), flood risks (inland and coastal, across pristine and developed areas), soil trafficability, and crop productivity in reference to forest plantations. The value of these research- generated interpretations range from academic to practical. In forestry, applications deal with planning forest operations, including the layout and access to harvest blocks, locating wood landing points, deciding where to plant what, and deciding which areas to protect against heavy machine traffic. Also of note is the on-board navigational use of the wet-areas map on mechanized forest harvesters to maintain machine movement on dry land, day and night, and when the ground is covered by snow. In park management, uses vary from trail and campsite selection to habitat and corridor delineations of wet-area obligatory species as these may refer to mammals, birds, amphibians, and to rare and unique vegetation. For communities, wet-area flood mapping is gaining interest within the general context of climate change adaptation. Each of these applications involves considerable research in terms of further map refinements, improving map-to-field conformances and accuracy, and expanding practical relevance.

We also develop new tools that enable end-users to work with the Centre-generated maps and other datalayers for specific purposes. Of note is the TRAIL tool, which allows our partners to optimize road and trail locations with full knowledge of trafficability risks and constraints. These refer to crossing steep slopes, wet areas, and, number and size of flow channels. The tool also highlights which areas should be avoided or preferred based on user- specified choices – since the application of this tool may range from planning logging roads to mountain bike trails.

Do you collaborate outside of the Centre? If so, what value does this bring to your projects?

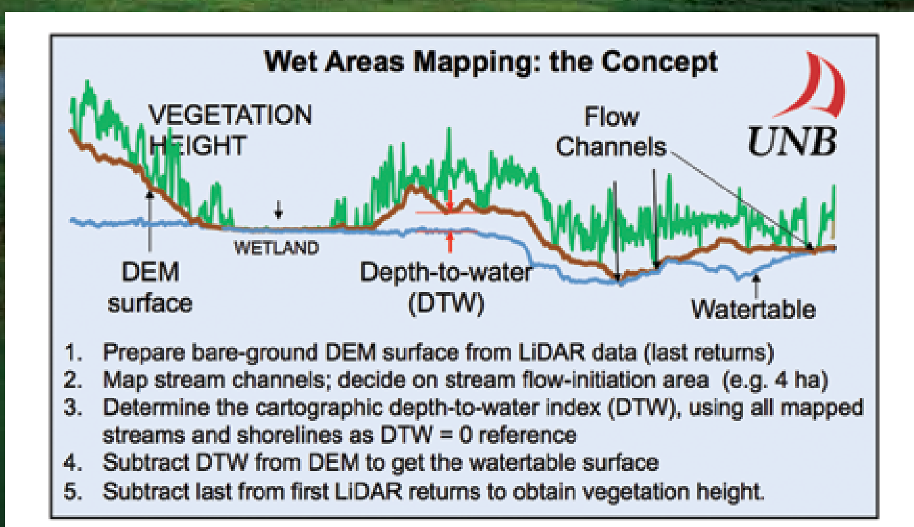
External collaborations connect the Centre with many partners, universities, industry and government departments and non-governmental organisations. These partners encourage and support further wet/dry areas mapping research, and are instrumental in testing new mapping applications. For example, municipal partners are interested in knowing which of their particular areas are affected by flooding if their hydrological infrastructure works as intended, or what would happen if this infrastructure fails in part or altogether. By gaining an understanding of potential failures, partners can prioritise their hydrological infrastructure plans and related maintenance schedules.

How does the Centre transmit its findings to other organisations, and affect knowledge transfer?

The Centre communicates formally and informally with its partners and wider audiences through seminars, meeting, workshops, conferences and website. The latter is updated from time to time to inform about new initiatives and applications. The website also provides background details about the Centre's activities by way of themes, posters, news, videos and publications.

of time. Secondly, only specific areas can be mapped at any one time – further land use requires surveys. Thirdly, certain types of terrain cannot be surveyed using traditional methods – mountainous regions, poorly drained areas and densely vegetated terrains can be particularly problematic. Finally, the results would depend on the timing of the survey, and would also differ by surveyor and survey methods.

The issue of wet-areas mapping across large spaces was addressed and has – to a considerable extent – been resolved at the University of New Brunswick (UNB)'s Forest Watershed Research Centre. The mission of this Centre is to use watersheds as its primary research focus to resolve biophysical issues arising from forest management, and land management in general. The solution of the wet-areas mapping problem comes in the form of digitally delineating flow channels and adjacent soil wetness regimes by way of depth-to-water (DTW) maps. These maps emulate the depth to the water table within or below the soil in relation to the elevation difference between any point in the landscape and the nearest open-water locations. These locations refer to all mapped streams, ponds, lakes, rivers and shores. This



kind of mapping provides an efficient base map for field operations timing and planning.

MAPS AND MODELS

The wet-areas mapping initiative converts digital elevation data such as those generated through air-borne light detection and ranging (LiDAR) technology into useful elevation-derived maps. This technology acquires its data through laser-light emission and reflection scanning at a rate of about 400,000 pulses per second. The gathering of all surface reflected pulses then generates a cloud of point data which – through further processing – provides high-resolution elevation data for all the features on the land, (ii) the ground

INTELLIGENCE

WET AREAS MAPPING OBJECTIVES

- To address how soil wetness and topography influence natural soil properties, processes and impacts at the watershed level across landscapes
- To develop practical solutions and tools to mitigate potential impacts due to off-road trafficability
- To improve sustainable efficiencies in land and crop management

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Research visibility

The Forest Watershed Research Centre uses a number of platforms to disseminate its work – but perhaps one of the more innovative among these are the videos on its website. This includes a particularly revealing two-minute animation showcasing the wet-areas mapping initiative and how LiDAR point cloud data translate into digital wet-area landscape maps with and without forest cover. The video, as it was immediately picked up by 'LiDAR News' (http://blog.lidarnews.com/lidar-based-wet-areas-mapping-video), has achieved about 7,000 hits since being uploaded, and as Arp enthuses: "This video is steadily reaching local to international audiences, from general to professional points of view".

Other video releases on the website feature wet-area talks from the researchers and from end-users working in, eg. forestry, park management, environmental consultancy and energy extraction. One film is running to a full hour, where Jae Ogilvie, Research Associate at the Centre with geospatial analysis specialisation, discusses technical details of the wet-areas mapping processes, giving a point-by-point analysis of how the mapping progresses digitally from small to large areas. A talk given by Arp addresses wet-areas mapping in the context of climate change adaptation is also available for download.

Aimed at a broad audience, these videos are viewed by members of the public and researchers at other universities and other research institutions. It is hardly a conventional way of distributing research findings and developing impact – but for the New Brunswick group – the use of this digital medium proves to be highly successful, and especially so in combination with an accumulating body of peer-reviewed wet-areas mapping publications.

elevation for fields and forests, and (iii) the height of structures above ground, including vegetation.

Using LiDAR-generated bare-earth DEMs alone produces flow-channel and wet-area networks that can be varied by changing the starting point of each flow channel using preset values for minimum upslope areas that contribute to stream flow initiation. For example, end-of-summer stream channel networks on land covered by glacial till tend to have an upslope water accumulation area of about 4 ha. This area progressively shrinks to 0.25 ha and less as the weather becomes progressively wetter towards the winter and the snowmelt seasons.

BROAD BENEFITS

The benefits of wet-areas mapping have been phenomenal for the Centre partners and other end-users. Essentially, the distributions of soil type, drainage, soil moisture regimes and soil trafficability can all be determined from the wet-area maps with high fidelity. Extensive field tests have proven that LiDAR-generated maps are particularly effective in predicting flow channels and wetland borders, often with an accuracy of about six metres, nine times out of 10. "This is a huge leap forward, especially across forested lands where trafficking over previously unmapped flow channels and wet areas can make wood harvesting and transporting costly and messy," Arp explains. As a result, the Centre-generated wet-area maps often translate into better and cleaner field operations while saving time and money, and have been referred to by some of the users as a route to 'surprise-free planning'.

The user base for these maps has been far broader than originally expected, and now ranges across local to national and international jurisdictions. To capitalise on this diverse relevance, the Centre continues with its research projects to further improve and diversify its wet and dry areas mapping processes, and to augment the functionality of the resulting maps for specific user groups and their particular information needs. For example, ongoing research involves: correlating the depth-to-water index with the occurrence of vegetation types and communities according to their soil moisture regime preferences; forecasting forest plantation yields based on the varying levels of soil moisture and drainage conditions within plantation areas; building tools that optimise user priorities and preferences with regard to the placement of roads, trails and other routes. Reflecting on their accomplishments, Arp admits: "The growing interest in wet-areas mapping continues to amaze".