Alaska Megaprojects Bring New Demand for Hydrological Studies

Summer is here, so AUTC researchers and their partners are on the move. Across Alaska, teams are fanning-out with four-wheelers, helicopters, bush planes, rafts, and hip waders to measure all-things hydrology in Alaska. As melting snow joins with summer rains to cause massive runoff and floods, the State of Alaska has questions that are leading researchers farther afield to look beyond stream flows at larger-scale hydrologic trends.

To withstand all the forces brought by Alaska’s extreme climate, transportation infrastructure must be designed to account for a wider variation in weather and hydrology than anywhere else in the nation. This is especially true for current and future transportation corridors with road, rail, and pipeline infrastructure, many of which are among the highest priority projects for the State of Alaska. Together, new infrastructure ‘megaprojects’ are making hydrology and glacial studies more important than ever for Alaska’s engineers and planners. For that reason, AUTC has partnered on multiple studies with the Water and Environmental Research Center (WERC) at the Institute of Northern Engineering.

Alaska’s Glaciers

Climate change is manifesting new dynamics in Alaska’s glacial basins, which demonstrate some of the highest glacial wastage rates on Earth. From 1995 to 2001, Alaska’s glacier wastage nearly doubled the estimated annual loss from the entire Greenland ice sheet in the same time period.

These trends will continue, according to scenario-based climate projections that predict Alaska’s glaciers will lose more than half of their current volume in the next century. As glacial melt accelerates, research indicates increases in glacier runoff that will exceed all other runoff components in a particular watershed. Studies of multiple gage records have already detected runoff increases in glacial streams along Alaska’s southeastern coast.

The resulting stream flows affect the physical properties of streams such as overflow and stream reorganization, which have downstream impacts for engineers working with culverts, bridge crossings, or unstable slopes. As Alaska’s infrastructure networks connect multiple regions with unique varying climates, planners must understand hydrologic trends on a statewide basis.


Director’s Notes

This issue of AUTC’s newsletter shows the variety of our projects, but it also highlights how partnerships enrich the quality and relevance of our work. Because many of Alaska’s engineering challenges are unique to cold regions, our transportation professionals often face obstacles that require both highly specialized expertise and localized knowledge. In this issue, we discuss several AUTC partnerships that are bringing new technology, data, and innovative applications to bear upon Alaska’s significant challenges—safety, asset protection, and responsible resource development.

To help Alaska DOT&PF respond rapidly to unexpected winter storms, AUTC is partnering with the National Center for Atmospheric Research (NCAR) and the UAF Weather Center to implement a winter road Maintenance Decision Support System (see page 3). After adding in-vehicle temperature and humidity data collection systems, we are now able to predict the temperatures around the Fairbanks area within 3°F. In an area where temperatures can vary 20°F within a mile or so, this is a great leap forward. As I was driving to work after a major snowfall, I was surprised to see all of the major intersections free of ice and snow. A quick phone call to our Alaska DOT&PF Northern Region partners confirmed my suspicions: they had used the new system to predict unsafe road conditions and take action at specific locations with confidence. Alaska DOT&PF intends to implement this system statewide.

AUTC and Alaska DOT&PF are also working with a local contractor on a first-of-its kind answer to Alaska’s bridge deck preservation challenges (see page 4). We are showcasing a new technique for applying Magnesium Phosphate Concrete in bulk to rehabilitate bridge decks. While the use of Magnesium Phosphate Cement is by no means new, an Anchorage company named Apun has developed a technique that allows the cement to be mixed in a nozzle and placed on the bridge deck and finished in quantity before it sets. This means the deck can be returned to service in a matter of hours. While the process is quite new, it certainly has the potential to revolutionize bridge deck repairs. We’ll keep you posted on this as we learn more.

Hydrology is another area of our partnered research. AUTC has ongoing collaborations to gather statewide hydrologic data for Alaska’s proposed infrastructure ‘megaprojects,’ like hydro-electric energy, and new road/rail corridors for energy and mining activities (see page 1). Planners are designing new infrastructure in regions which have almost no hydrological data to design roads, bridges, embankments, stream crossings, culverts, and other features. To meet this need, AUTC has paired hydrology and glacial experts with ongoing studies that cover entire regions—the Susitna River Basin, Jarvis Glacial Basin, the North Slope, and the Brooks Mountain Range, respectively. Unlike most places, rainfall and snowmelt are only partial contributors to stream flow levels, as glacier melt is frequently the dominate source of water. Combining field research with remote sensing and climate modeling, these partnerships are providing the kind of region-wide synthesis of data and analysis that planners need.

Finally, the AUTC Student of the year is Jason Zottola, who has been at the center of our research partnerships on frozen ground studies. Jason’s work in the impacts of ground water movement in permafrost is pioneering and will help us understand the implications. This study which was undertaken with our Canadian counterparts is truly an international collaboration, and has greatly advanced our collective knowledge about a vexing issue for cold region transportation engineers.
April 30th brought an unpredictable winter storm to Fairbanks, Alaska. Temperatures dropped, rain and snow fell, and the Alaska Department of Transportation and Public Facilities (ADOT&PF) issued travel warnings, cautioning the public of dangerously slick conditions. By morning, the town was covered in ice and the surrounding hills had eight to 18 inches of new snow. While the weather brought nothing new for Northern Region Maintenance and Operations crews, they had a new trick up their sleeves. Drivers noticed that while most roads were still covered in ice, major intersections, bridges and congested areas had been selectively treated. Depending on these factors, managers decide on a treatment strategy—where, when, and how much—as well as a treatment material, the right mix of sand, anti-icing, or de-icing solution. With limited staff, fleet, materials, budgets, and time, these factors force managers to make fast decisions to improve public safety and allow commerce to flow efficiently after surprise storms.

Such was the case on April 30, when Northern Region began assessing the incoming storm. Dan Schacher, Fairbanks District Superintendent, is responsible for maintenance and operations in a district described as the largest and most complex of any within Northern Region. The MDSS prototype was only partially installed on this day, providing just the weather and climate information without the other supporting analysis tools. Even with the partially functioning MDSS prototype, Schacher could make predictions based on pavement surface temperatures accurate within three degrees Fahrenheit. Schacher must predict multi-hour periods in which the temperature stays above 15 degrees Fahrenheit—the threshold for certain treatments to remain active. The prototype lets Schacher access specific real time data from multiple locations across his district to make a more fully informed decision. Without this information, he would need to drive across town to specific locations with a manual laser pointer to read and compare pavement temperatures and make an educated guess. So, when this storm took Fairbanks by surprise, Schacher and his team at Northern Region had an advantage that led to a more effective response.

Managers had implemented a system to enhance rapid decision-making during emergency anti-icing and de-icing operations, a winter road Maintenance Decision Support System (MDSS). The system was only partially developed, but gave managers access to real-time weather predictions to prioritize and allocate vital resources.

MDSS Decision Tools

The National Center for Atmospheric Research (NCAR) is leading an effort to create a MDSS prototype for winter road maintenance. Working through AUTC, NCAR partnered with Alaska DOT&PF’s Northern Region and the Research Development and Technology Transfer Section to adapt an MDSS to Alaska’s extreme and complex climates.

An MDSS system uses road condition and climate data to deliver managers recommended treatment strategies formulated on standard practices. It also utilizes data collected every 30 seconds from instrumented plow trucks and other fleet vehicles. Factors such as air and surface temperature, humidity, precipitation, wind, and others inform the system during late-breaking decisions about road treatments.
Preserving infrastructure assets in Alaska is fraught with extreme challenges, most often borne by the region’s harsh and variant climates. Bridge decking—the focus of multiple AUTC studies—has become an increasingly important area of interest for Alaska DOT&PF. It has also risen to the fore of national transportation policy, as pavement and bridges have become a focus of one of seven target areas for Congress’ recently enacted funding under Moving Ahead for Progress in the 21st Century Act (MAP-21).¹

For Alaska, these concerns are not new. In recent decades, Alaska DOT&PF has worked with crews and contractors to develop innovations for bridge deck preservation in the face of changing climate, rising materials and labor costs, and increasing pressure to minimize lane closures and related inconveniences to commerce and the travelling public. They also face infrastructure assets approaching the ends of their life cycles. Much of today’s concrete is 40-50 years old, meaning that many of Alaska’s bridges and decking surfaces leave engineers with only two increasingly costly options: repair or rebuild.

At the heart of Alaska DOT&PF’s trials in bridge deck preservation is a decades-long struggle to utilize an alternative surface treatment known as Magnesium Phosphate Cement (MPC). As an experiment this past summer shows, Alaska DOT&PF and its contracting partners are on the verge of an innovation with international applications that could change bridge deck management forever.

**The Dalton Decking Experiment**

MPC has been an item of interest for Alaska DOT&PF since the 1990s, when it enabled a major accomplishment on the Dalton Highway. Northern Region M&O crews replaced the standard Ordinary Portland Cement (OPC) with an experimental application of MPC on a series of wooden bridge deck replacements in conjunction with pre-cast panels. They were looking to explore the benefits and potential uses of MPC beyond its efficiency as a quick spot fix.

Fundamentally different than OPC, MPC sets up with the strength of concrete in an hour, and demonstrates low permeability. Nor is it new. Its use traces back to the Great Wall of China and many historic Indian stupas still visible today. More recently, MPC has been used since the 1970s as a go-to method for quick patches and repairs. Its fast setting time allows crews to apply it to a hole, crack, or worn surface, and move on to the next spot. In limited doses, MPC proves a durable, cost-effective quick fix. Crews can fix multiple spots on a surface, and then let traffic resume in about an hour.

In 1992 crews completed work on an ambitious project replacing old timber decks on 18 bridges along a 128-mile portion of the haul road, and resurfacing and joining them with MPC. Completed in just eight months, this extensive operation showed engineers MPC’s benefits, but it also exposed some challenges, like the need to apply MPC fast enough to keep pace with its quick set time, and the cumbersome task of applying MPC bucket-by-bucket.² Because of the scale of operation, labor and material costs, and other factors, this broad application of MPC was also quite expensive.

**Portage Creek Bridge**

Two decades after the Dalton decking experiment, Alaska DOT&PF conducted another MPC application on the Kenai Peninsula. A Maintenance and Operations crew conducted an informal experiment on the Seward Highway at a bridge near Portage Glacier Road. 543 feet long and just over 34 feet wide, the bridge was like many the department deals with—aging, and in chronic need of repair.

The area’s climate—defined by its proximity to the ocean, glacier-fed streams, and drastic seasonal variations—brings a

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¹ Moving Ahead for Progress in the 21st Century Act, 23 U.S.C. Sec. 119 (e) (8), MAP-21 Sec 1106.
² Pioneering Precast in Alaska, in Highways for Life, a publication of the Federal Highway Administration, U.S. Department of Transportation.
constant threat of water. Alkali-Silica Reaction (ASR) refers to a chemical reaction causing concrete expansion and cracking. ASR occurs largely due to water infiltrating concrete and aggregate, and is among the most persistent and common threats to concrete. In the past, typical patch and repair jobs on this bridge were quickly infiltrated by water, which began a freeze-thaw cycle leading to more cracks, holes, and slumping.

A solution to ASR, MPC is unique in that it forms a chemical bond—not a glue or a mechanical bond—that expels, rather than attracts, moisture. This factor makes MPC a very attractive surface treatment because of its extended life cycle, and its ability to prevent the kinds of repeated repair costs associated with OPC. These repeated costly repairs made Alaska DOT&PF wonder if they could somehow apply MPC over an entire bridge deck. One challenge remained: applying MPC quickly, and in bulk.

Apun, an Anchorage-based pavement preservation company, had a history of providing products and services to the department. Having recognized the potential uses of a mechanically mixed and placed MPC, Apun had already developed Alaskrete MPC and a trailer mounted machine to dispense it on a small scale for potholes and spalled areas. In order to accomplish a complete bridge deck overlay, they developed a prototype pump head to fit on the end of a cement mixing truck's pouring chute. The head allows the team to mix and pump a higher volume of MPC, getting it on the ground quickly before it sets.

As the tourist season slowed on the Seward Highway, crews began their work. On their first day, they closed one lane of traffic, prepped the bridge, set laser levels to ¾ inch above the deck, and began rapidly applying MPC. On the second day, they alternated the lane closure and completed the same process and treatment. In one treatment, the crew applied 200 feet of MPC in three hours, and maintained a pour rate of three to four tons per hour.

Since then, one winter has passed and the team has seen no problems—no cracking, no damage, and no signs of water infiltration.

**MPC Benefits**

Beyond improving performance and reducing repair costs, MPC can be developed for specific locations, surfaces, and climates—making it an adaptive option for Alaska’s diverse and extreme regional climates. According to the Cold Climate Housing Research Center, MPC demonstrates a much higher compressive strength than OPC. A 2008 CCHRC study found that MPCs show a compressive strength of 8,000-12,000 psi, while the compressive strength of OPC was 3,000-7,000 psi.\(^3\) In this study, MPC also demonstrated improved Bending Tensile Strength (in psi), salt tolerance, self-bonding, and a lower curing temperature range more appropriate to Alaska’s climate.

Minimized lane closures are also a benefit. With current technology, a crew using OPC could spend one month prepping a bridge, then spend one to two weeks of lane closures. Crews using OPC for bridge decking repairs must often grind down the existing surface before applying cement. Using MPC on the other hand, crews can skip this process altogether. They simply blow off the surface to make it clean, and begin applying MPC. Traffic can resume in an hour.

**Next Steps**

For Alaska DOT&PF, the goal behind MPC is to make concrete repair more like asphalt repair, with immediate return to service, extended multi-year durability, and an ease of use made possible by custom designed equipment.

Alaska DOT&PF has expressed interest in further research and development activities, potentially reducing the costs of this new innovation. For a one inch overlay, current Alaskrete MPC costs of materials and application are approximately $20 per square foot with a 10-20 year service life. (For the sake of comparison these costs include only materials and application.) Compare that with an estimated $10 per square foot materials and application cost for fabric and HMA overlay with a 1-3 year service life.\(^4\) Additionally this 1 inch MPC overlay is half the weight of the 2 inch HMA overlay. With additional research and development into improved application equipment and techniques, Apun estimates these costs will continue to drop.

So what began as a cost- and time-intensive experiment two decades ago has evolved into an applied innovation that drastically reduces maintenance and repair costs on some of Alaska’s most vital transportation assets.

*Note: This story also appears in the current issue of Alaska Contractor Magazine.*

**Ordinary Portland Cement (OPC) vs. Magnesium Phosphate Cements (MPCs)**

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<th>Property</th>
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</tbody>
</table>


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\(^3\) Sonafrank, Cole. Substantially Superior Cements: An Introduction to Magnesium Phosphate Cements (MPCs) and Geopolymers, in CCHRC Snapshot RS 2008-01, Cold Climate Housing Research Center, January 15, 2008.

\(^4\) Quote Alaska DOT&PF, Denali District Maintenance and Operations.
STATEWIDE FLOW STUDIES

AUTC and WERC are utilizing large scale hydrologic modeling and ground-level physical measurements to assess the role of glaciers on lowland runoff across Alaska.

Anna Liljedahl, assistant professor at WERC, integrates multiple projects—all representing glacial basins—to better understand how stream flow may lead to critical infrastructure damage and costly disruptions to Alaska’s transportation system. Geographical areas of focus include the Valdez, upper Susitna, and Jarvis regions respectively, which offer a broad range of climate regimes. Partially funded by Alaska DOT&PF and AUTC, this team includes several counterparts from the University System and the Department of Natural Resources: Regine Hock (UAF-Geophysical Institute), Anthony Arendt (UAF-Geophysical Institute), and Gabriel Wolken (Alaska Department of Geological and Geophysical Surveys).

The team working on the Jarvis Creek watershed, in the Eastern Alaska Range near Delta Junction, also includes collaborators at the U.S. Army Cold Region’s Research and Engineering Laboratory (CRREL) and the Salcha-Delta Soil and Water Conservation District. Partly funded by Alaska DOT&PF and AUTC, the measurements include glacier mass balance, winter and summer runoff, groundwater levels, water chemistry and meteorology. Jarvis Creek flows northward to Delta Junction and crosses the Richardson Highway before its confluence with the Delta River. The study is characterizing runoff and melting mechanisms that, because of factors such as the watershed’s north facing orientation, help planners understand hydrologic responses of similar glacier basins in the state. By combining funding from AUTC, Alaska DOT&PF, the U.S. Department of Defense, and the National Institutes for Water Resources, this study expanded its scope and is maximizing the return on investment for each individual funder.

MEGAPROJECTS

Involving multi-billion dollar investments, public-private partnerships, expanded transportation modes, multiple stakeholders, and the ability to unlock significant natural resource and energy development, several Alaska megaprojects now depend upon an improved understanding of glaciers and stream flow.

Foothills West Transportation Corridor — Also known as the “Road to Umiat,” the proposed 100 mile long route would reach Umiat from the Dalton Highway near Galbraith Lake, crossing numerous waterways along the North slope of the Brooks Mountain range. Other options include building a connection between Umiat and the existing road infrastructure on Alaska’s Arctic Coastal Plain, or a route running south from the Prudhoe region.

AUTC’s partners at WERC have managed an extensive program of research on the hydrology of three North Slope rivers: the Anaktuvuk, Chandler, and Itkillik. Multiple research efforts led by Doug Kane (UAF-WERC), Bill Schnabel (UAF-WERC), Horacio Toniolo (UAF-WERC/CEE), Sveta Stuefer (UAF-WERC/CEE) and others have examined a variety of hydrologic dynamics on the North Slope such as sediment transport, precipitation, flow rates and frequency, snow/ice melting and breakup. This summer, multiple field teams are again embarking to remote locations at high and low elevations to conduct monitoring, instrument and weather station maintenance, and data collection on multiple stream and river locations. This ongoing work will help planners design for roads, bridge crossings, and other critical infrastructure. The project is going beyond informing planners, as the team has published a website with real time weather data from multiple weather stations at: http://ine.uaf.edu/werc/projects/foothills/foothills.html.

Road to Ambler — The proposed road and transportation corridor would run west to the Ambler mining district through the southern foothills of the Brooks Mountain Range, originating on the Dalton Highway near Bettles. Current route options put the road’s potential length somewhere between 920 and 240 miles long. Project cost estimates are still developing and vary greatly depending upon multiple variables, such as a
one- vs. two-lane route. Also, depending upon the final route selection, the road could make between 10 and 13 river/stream crossings, but the state lacks information about the characteristics and loading of sediment for major rivers that run across the routes. Considering that bridges on this route will cost an estimated $30,000 to $40,000 per lineal foot to construct, designers are pressed to have the best stream flow estimates available to determine the size of a particular bridge—an important factor in the regulatory and permitting process.

Similar in scope and methodology to the North Slope hydrologic studies, an ongoing program of research at WERC is providing critical design data for state planners. With a combination of river gauging, multiple weather stations, remote data collection, and extensive field and site activities, WERC researchers are helping the state determine which route a road would take by helping illustrate the kinds of stream flow projections designers will face when designing for bridge crossings, pilings, embankments, and other infrastructure. To date, the team has also published a website about the project, and also made real time weather data available at: http://ine.uaf.edu/werc/projects/ambler/.

VALUE ADDED RESEARCH

Although distinct from one another in a myriad of ways, these megaprojects share one defining characteristic in that they bring together a broad collection of Alaska stakeholders from the public, private, and academic sectors. With this in mind, AUTC, WERC, and other partners work collaboratively to expand the scope of research, reduce and share project costs, and enhance the multi-disciplinary expertise available to Alaska’s decision makers.

Susitna Dam — Also called the “Susitna-Watana Hydroelectric Project,” the proposed 735-foot hydro-electric dam would create a 42-mile long reservoir along with supporting facilities and access in the Susitna River Basin. Costing an estimated $5.2 billion, the dam would sit between three major upstream rivers and four major downstream rivers. If built, it would be second largest dam in America. Liljedahl is working on a study to produce detailed hydrological projections of the Susitna drainage basin to illustrate how future permafrost degradation and glacier wastage may impact runoff into the proposed dam. In March, at the annual conference of the American Water Resources Association—Alaska Section in Anchorage, the Susitna-Watana research team emphasized the need for high-elevation weather stations to better understand the distribution of precipitation. Here, the Alaska DOT&PF and AUTC complement funds received from the Alaska Energy Authority by allowing the installation of an additional meteorological station in the mountains, which revealed critical information during the massive flooding event in mid-September 2012. The team is now receiving and assessing data from these locations in order to reduce the uncertainty in their hydrological model simulations.

Enhancing Winter Road Maintenance

Implementing MDSS

Already realizing the system’s benefits prior to complete implementation, Northern Region is looking forward to having the system fully up and running this year. The MDSS is partially deployed and has undergone multiple field tests, and been instrumented into 25 maintenance vehicles. Its 79-hour weather assessment and prediction model has been developed and proven reasonably accurate.

To fully deploy the MDSS in Alaska by fall, the study is configuring a weather forecast system and a pavement condition and treatment module to anticipate weather trends and suggest appropriate treatment strategies.

The next step for this research is to integrate the treatment selection suggestions and the full spectrum of incoming data from instrumented vehicles. The research group is also inviting feedback from Alaska DOT&PF’s Central and Southeast regions on potential uses they may have.
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