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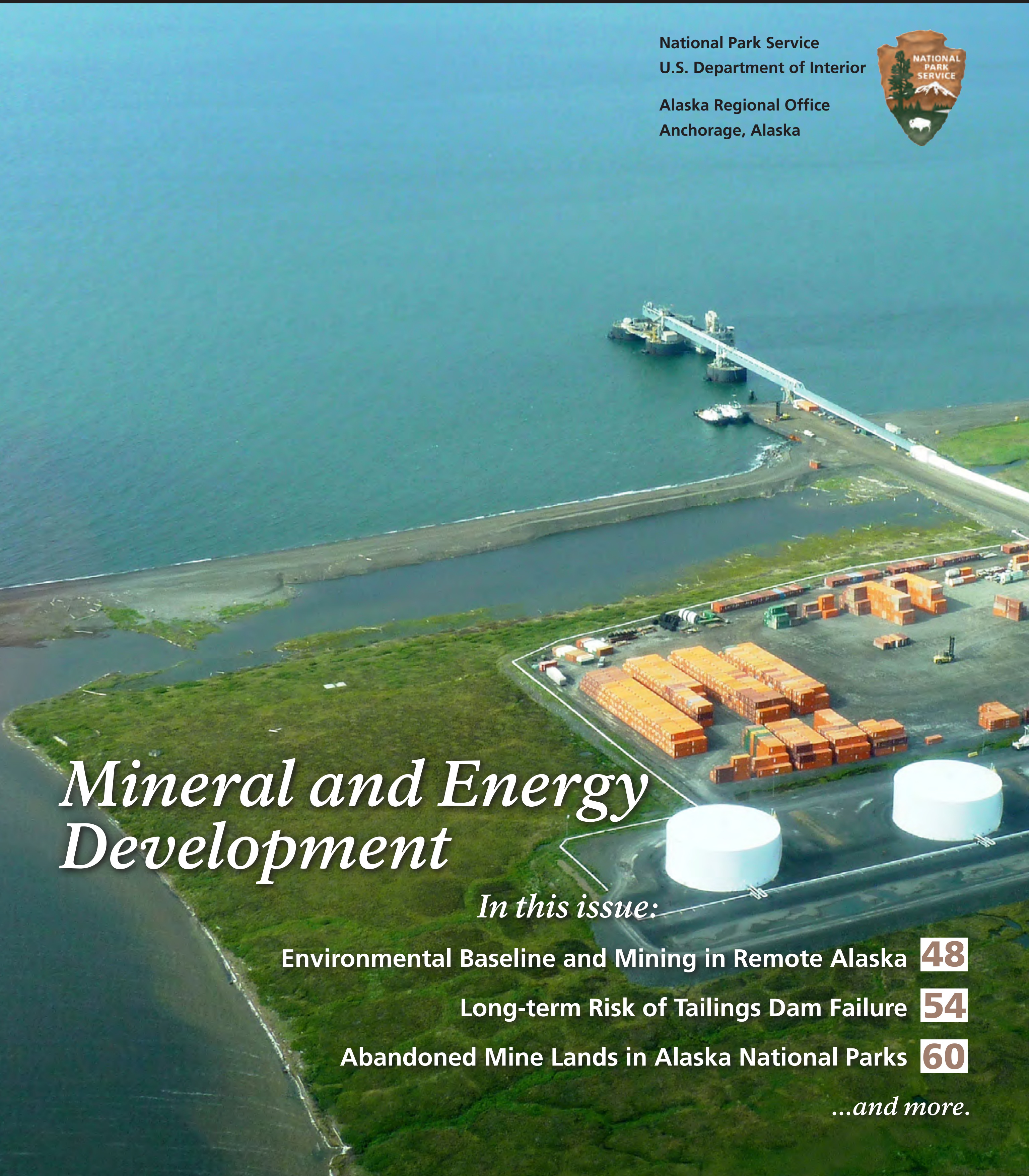

Mineral and Energy Development

In this issue:

...and more.

Volume 13, Issue 2

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Cover photo: Red Dog Mine, Port Site 3 in Cape Krusenstern National Monument.

Photo by Tahzay

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Opposite: Dan Creek, Wrangell-St. Elias National Park and Preserve

Photo by B. Giffen

Nature and Resources

By Robert Winfree

This issue of *Alaska Park Science* covers a lot of ground: land status, mining history, natural and cultural resource protection, reclamation, and hazard abatement. Our articles are drawn from Alaska where mining and oil extraction are generally separate activities, and Canada where oil sand operations involve both. There's no denying that energy and mineral extraction have been and will continue to be important across the North for a long time. Mining and energy-related industries provide direct and indirect employment for thousands of people, taxes and other revenues that support governments, and supplemental income for Alaska's residents through the Permanent Fund Dividend. Small-scale mining, mineral collecting, mining lore, and history are also popular activities.

The National Park System has a long and varied history with mining and energy development. Many parks contain prehistoric evidence of mining and quarrying activities, traditional practices that remain important today for many cultures. Stephen Mather, the first director of the National Park Service (NPS), earned a fortune in mining "20-Mule Team Borax" before redirecting his efforts to building the National Park System. Today, there are existing mining claims in NPS areas across the country, and oil and gas extraction activities in 13 areas. Although staking of new mining claims is no longer allowed in parks, NPS recognizes existing claims and honors the ingenuity and determination of countless miners, processors, transporters, and the communities they helped to build, through historic preservation and interpretation (*Beckstead 2005; Kain and Brease 2006; and Ringsmuth 2011*).

Figure 1. Three Mines Below Castle Mountain. This painting by the author shows the Kennecott Mill complex and mine-related structures on the mountains and glaciers overhead. Kennecott is a popular tourist destination within Wrangell-St. Elias National Park and Preserve and is our best remaining example of early 20th-century copper mining. Nearly $200 million worth of copper was removed from these mountains between 1911 and 1938, employing up to 500-600 people in the McCarthy, Alaska, area during peak operations. (http://www.nps.gov/wrst/historyculture/kennecott.htm)

Personally, I've been intrigued by mines and mining since childhood, when I searched for crystals around an abandoned colonial-era mine near home. My university coursework in geology, a career in natural and human ecology, and countless visits to mining and energy-related sites helped me to understand that responsible resource development depends upon information gleaned from many fields of study. I'm also old enough to remember when unprofitable mining and drilling sites were sometimes shut down or even abandoned with scant attention to long-term safety hazards, contaminants, and off-site resource damage from mine drainage. Some old mine sites have been reclaimed, restored, and even repurposed as parks and recreational sites (*Figure 1*), while others became eyesores, environmental and safety hazards, economic liabilities, or "all of the above."

During the last half-century, many new laws, regulations, bonding, and other requirements have been applied to prospecting, mining, drilling, and related activities. Some requirements apply broadly, while others pertain specifically to activities on federal lands, including parks (e.g., 36 CFR 9B, 16 U.S.C 39, 16 U.S.C. 3150, P.L. 88–577). Reclaiming a mine or well site, mitigating safety hazards and environmental impacts, and preserving historic context is challenging work (*Adema et al. 2011; Griffiths 2005; Griffiths and Kucinski 2005; Hovis 2005; Ringsmuth 2011; Stromquist 2005; Stromquist in this issue; Ireys in this issue*). Despite considerable advances in site reclamation and remediation, our capacity to remove or contain hazards, or reclaim or restore severely altered landscapes often remains limited by technology, information, and economics. Closure requirements continue to evolve with experience, sometimes changing between when operations began and when they come to an end (*Richens et al. in this issue*). Even with best available technology, final closure can require work for decades after the profit-making activities are finished.

Demand for energy and raw materials is certain to continue into the foreseeable future. Many factors will determine where mineral and energy extraction activities expand and where they don't. Our need is also certain to continue for science, engineering, and scholarly research; to develop safe, effective, and affordable technologies; to protect, preserve, and restore the natural and human environment; and to record and communicate our history.

Photo by Thomas C. Klein Jr.

Figure 2. A male sockeye salmon defends his territory.

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REEVE AIRWAYS

Bob Reeve: Eastern Alaska's Early Air Prospector, 1932-1938

By Katherine Ringsmuth

Bob Reeve is arguably one of Alaska's most recognizable bush pilots. Although his independent airline, Reeve Aleutian Airways, pioneered commercial routes from Anchorage throughout the Alaska Peninsula and the Aleutian Chain between 1947 and 2000, the pilot is most known for his ability to land and take off from glaciers located in a region that would become Wrangell-St. Elias National Park and Preserve. But what is often overlooked in the accounts of Reeve's early aviation activities in the Wrangells is the role that Alaska's mining industry, bolstered by New Deal legislation, played in launching the "glacier pilot's" historic flying career.

After his first flight in 1932, Reeve became an astute student of the towering peaks surrounding Valdez. While circling summits and studying the tongues of ice that flowed forth from the barren, steep slopes, the pilot, with a prospector's instinct, remembered thinking, "It was hard to realize that in such an inhospitable, nearly impassable land lay the riches of the earth" (*Day 1961*). The so-called "easy-to-gather" ore had long since disappeared from Alaska and the Yukon, and by 1932, "Valdez," as Reeve described it, "was a dead town" (*Day 1961*). But prompting Reeve's interest were claims made by geologists that rich quartz lodes still lay in the inaccessible mountains and were scarcely touched because of the expense and physical labor of reaching them. Besides the famous Chugach mines that once made Valdez a mining hub before the Great Depression, Reeve guessed that the Wrangell Mountains stretching eastward, with little or no distinguishable break on the horizon, held the type of riches that to the pilot meant more flying and a promising future.

Bob Reeve File. Alaska Aviation Heritage Museum, Anchorage, Alaska.

Figure 2. Pilot Bob Reeve drifted into the coastal town of Valdez in spring 1932. A self-proclaimed maverick of the Wrangell's aviation scene, Reeve embraced an old frontier style, which he strongly conveyed while testifying to the Civil Aeronautics Board in 1939. Reeve felt that in the dog-eat-dog competition for Alaska aviation business, "Only the toughest—and the shrewdest—survive." Bob Reeve is pictured standing in front of his Fairchild aircraft, which he used to airlift supplies to mining operations throughout the Wrangells between 1932 and 1937.

Figure 1. Reeve felt at home above the towering peaks of the Chugach Range. While circling summits and studying the tongues of ice that flowed forth from the barren, steep slopes, the pilot, with a prospector's instinct, remembered thinking, "It was hard to realize that in such an inhospitable, nearly impassable land lay the riches of the earth." Pictured is Reeve's Fairchild, which he used to serve lode mines near Valdez.

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Winter Flying in the Wrangells

It did not take long for Reeve to encounter extreme weather conditions, which provided him a strong awareness of the natural surroundings that, among other things, was crucial for success in Alaska's aviation business. Flyers understood the region as a land of contrast and change. "The way of the pilot is hard in that country and the perils which lie over and beneath the white blanket of snow are many," warned the New York Times in 1932. "In the Alaskan winter-time this means . . . a fight for life." "It is no wonder," remarked writer Harmon Helmericks, "that the old pilots were all weather-wise."

To Reeve, being "weather-wise" was simply part of the job, a skillset he most certainly perfected during his first contract work in the Wrangells. The job consisted of flying supplies into the isolated Chisana region. At the time, the only way into or out of the struggling year-round mining camp was hauling supplies over the mountains by horse and sled, or if one could afford it, charter a flight with Gillam Airways. Reeve was hired to fly supplies to Chisana at twenty cents a pound—an affordable price. In order to keep costs low, Reeve found the most efficient way to fly in goods was to truck fuel and freight up the Richardson Highway from Valdez to Chistochina, where he based his rented Eaglerock at the Chistochina roadhouse. From there he flew supplies over the Wrangells to Chisana.

By 1932, roadhouses were well equipped to serve Alaska's flyers. Instead of dog mushing kennels, many roadhouses now provided airstrips, encouraging weary pilots to stay overnight. The Copper Center roadhouse, run by Florence "Ma" Barnes, was a preferred base for flyers because it offered a telephone line on which pilots could call in for weather reports. By mid-November in the Copper River Basin, temperatures drop as quickly as the daylight disappears. No matter the duration of the flight or how tired they were, pilots, in the age before the invention of antifreeze, immediately drained the oil from their plane upon landing. If a pilot neglected this critical procedure, the oil would freeze like water, irreparably damaging the engine. Reeve recalled that during these first winters he had to beg the roadhouse proprietor to allow him to warm the oil overnight near the stove. Through cooperation and good manners, Reeve found that the cooks became "as plane-wise as the flyers," for they routinely set the oilcan next to the stove before they started to grill the hot cakes (*Day 1957*). Before taking off, pilots had to warm the motor with a fire pot, which had to be covered with a tarpaulin to keep wind from extinguishing the flame.

Chisana miners anticipating Reeve's arrival often met his plane at the airfield. "A bush pilot was expected to serve as mailman, message-carrier, and purchasing agent for the men who stayed the year-round at the mine sites," recalled Reeve. Like the roadhouse staff that accommodated pilots, to the isolated miners who appreciated items brought to them from distant markets, pilots recognized their role in a new elaborate system linking Alaskans to the modern world. Still, Reeve maintained that instead of transporting modern American life—along with its commodities, technologies, and business—into the most remote places of the north, his air services carried on a spirit of frontier Alaska. "It was much more than a packet of needles or a can of snuff. It was their assurance that they were still a part of the outside world," explained Reeve, "and it was a tradition of Alaskan fellowship" (*Day 1957*).

In spite of Reeve's contention that aiding isolated miners was the Alaska way, during the worst years of the Depression, the gesture nevertheless lacked good business sense. As Reeve himself pointed out, it was always difficult to receive actual payment from them. So instead of concentrating on cash-strapped miners, Reeve began to specialize in the transport of freight. His competition in the Wrangell Mountain area seemingly preferred to fly people, because passengers could, as Harold Gillam put it, "use their two legs" to walk off his plane. The pragmatic Reeve had a different view. His response to Gillam: "It [freight] didn't ask questions" (*Day 1957*). But more importantly, the mining companies that chartered flights with Reeve generally paid their bills.

Aviation's Golden Era

It turned out that Reeve started his airfreight business at the perfect time. Even though the mining giant Kennecott Copper Corporation had temporarily closed its mines, which marked the inevitable decline of the region's copper production, the impact of the Depression cut costs for equipment and other supplies, which exponentially reduced overhead costs for gold lode mining operations in eastern Alaska. Additionally, Congress passed legislation in 1932 relieving owners of the obligation of having to conduct annual assessment work, except those who were required to pay federal income taxes. Most significantly, however, prosperity in the gold mining industry came from new federal policies directed at replenishing the nation's precious metal reserves.

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Figure 3. One of Reeve's first jobs was to fly goods into the mining community at Chisana, located on the east side of the Wrangell Mountains. To save costs, he trucked fuel and freight up the Richardson Highway from Valdez to Chistochina, where he based his rented Eaglerock at the Chistochina Roadhouse. From there he flew supplies over the Wrangells to Chisana.

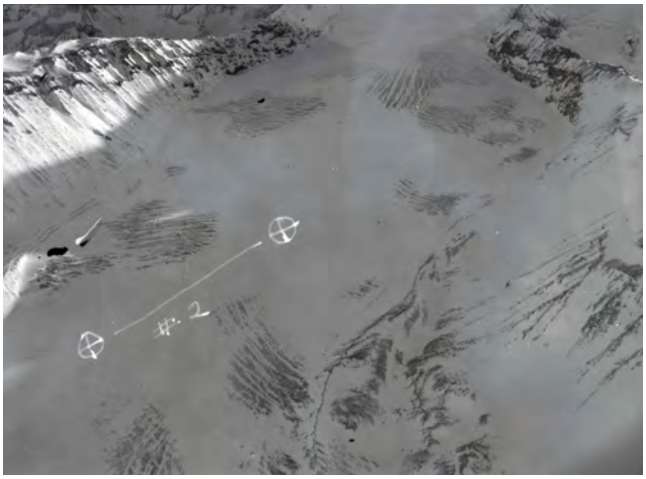

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Figure 4. After a series of trial and error attempts landing on the constantly changing and potentially deadly rivers of ice, Reeve perfected his new niche by paying close attention to the relatively unknown glacial environment.

Across the nation, desperate people were pulling their life savings from local banks, forcing them to close. Without capital available for new investment, the economy stagnated, coming nearly to a complete halt in 1932, the year Reeve arrived in Valdez. Soon after his inauguration in 1933, President Franklin Roosevelt signed a series of executive orders designed to prevent the run on and, ultimately, failure of banks, which culminated in the Gold Reserve Act of 1934. This piece of New Deal legislation made the Federal Reserve Bank the only financial institution that could legally buy gold. In fact, the law criminalized the holding or acquiring of gold by any U.S. citizen. The law also required that all newly mined gold in the country had to be purchased by the U.S. Treasury. Most significantly, the Gold Reserve Act increased the nominal price of gold from $20.67 per ounce to $35.00. The nearly doubling in value inflated the federal government's gold holding $2.82 billion overnight. The surge

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Figure 5. Bob Reeve fixed his Fairchild with homemade skis, and the mudflats that fronted Valdez was his airstrip, dubbed "Mudville" by his rivals. "While other pilots were operating by clock and calendar," recalled Reeve, "I began using a tide book for a manual of operation." Because work kept him mired in a muddy mess that smelled of rotting salmon and decaying seaweed, Reeve was known as a fairly filthy flyer. Not everyone was impressed with Reeve's dirty flying, however. Reeve's frequent advertising target, the meticulously clean Harold Gillam, remarked, "Reeve can have it!"

Figure 6. In early 1934, Reeve sought to capitalize on the economic upturn, placing an announcement in the *Valdez Miner* that read: "Prospectors, Attention! Gold is where you find it; but you can't beat the Chisana, Nabesna, Slate Creek, Chistochina and Bremner gold bearing districts as some of the best bets in Interior Alaska in which to make that pile." When a miner had his outfit ready to go, the ad insisted, "Always use REEVE AIRWAYS!" A similar advertisement was printed in the *Valdez Miner* in 1937.

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Figure 7. One of Reeve's mechanics who also helped him conduct the airdrops in those days was Valdez resident and fledging airman Bill Egan, Alaska's future governor.

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Figure 8. A so-called "scout of the sky," Reeve rebuilt and used Owen Meal's wrecked Eaglerock, and later his Fairchild aircrafts, to prospect for undeveloped mineral deposits throughout the Chugach and Wrangell Mountains. Besides transporting miners and supplies, his ties with the mining industry ran deep. Reeve owned 846 shares of Yellow Band stock at Bremner and even named his youngest son Whitham, for his friend Carl Whitham, owner of Nabesna mine. He was also part owner of the aptly named Ruff & Tough Mine.

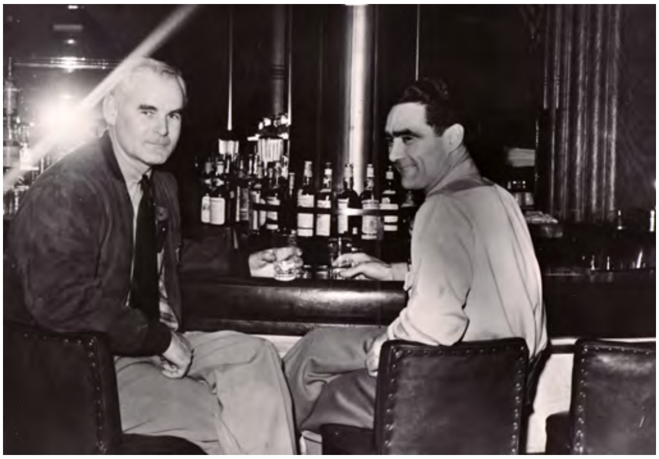

Photo from the Jack Peck File, courtesy Alaska Aviation Heritage Museum.

Figure 9. Although Bob Reeve and Harold Gillam respected each other as pilots, their views on government regulation of Alaska aviation diverged. Gillam believed regulation would make flying safer and more economical, while Reeve believed it would bring more government interference to flying. Pictured are Reeve and Gillam in Anchorage for the Civil Aeronautics Board Hearings in 1939.

Figure 10. Perhaps because Reeve perfectly adapted his flying to the seasons, writer Rex Beach called him a "Flying Ptarmigan." He even patterned his lead character upon Reeve in his 1939 novel *Valley of Thunder*. An example from Beach's book perfectly captures the "glacier pilot's" persona: "Anyhow he's a winter bird and he's doing the wildest flying I ever saw. He's carrying mine supplies up into the sawteeth—grub, gasoline, machinery, dynamite. When he can't find a landing place he drops it.". . . "I heard about him," Red admitted. "He dropped a Diesel engine by parachute. The guy is cuckoo."

Photo courtesy of Alaska Aviation Heritage Museum.

Figure 11. When Reeve died on August 25, 1980, an estimated 600 mourners attended his funeral service at the Sydney Laurence Auditorium in Anchorage. Pictured is Bob Reeve at the Reeve Aleutian Airways office in Anchorage, Alaska.

in gold prices also made it remarkably profitable to mine gold.

In Alaska, where stories of gold rushes and independent sourdoughs continued to resonate with citizens, the Gold Reserve Act gave a tremendous boost to the depressed mining industry. As Governor John Troy reported, "Never before have the material prospects for this Territory been brighter than now" (*Cole 1989*). Writer Rex Beach referred to such federal support as "a bit of intelligent government aid" (*Beach 1936*). Thanks almost entirely to an artificial, federally-controlled market, mines that had not been working for years suddenly reopened. The independent-minded citizens of the Last Frontier were too busy to be concerned that gold mining had become a noncompetitive industry.

Valdez, like other dormant gold rush towns, returned to life, as miners streamed into town with "cleanups" of gold bricks. Territorial journalists proclaimed the Prince William Sound port as "the Key to the Golden Heart of Alaska" (*Valdez Miner 1934*). Most significantly for flyers, mining investors could now afford to charter flights to remote prospects and develop new lode claims. While the country's economy would remain stalled for several more years, Alaska's revitalized mining industry took off with the help of the federal government and a new mining tool—the airplane.

Without the federal law significantly increasing the price of gold it is likely that Reeve Airways never would have left the ground. But the reopening of the high altitude lode mines, combined with increasing investment in exploration, kept Reeve in the air almost around the clock. For the summer months, Reeve made a deal with the mine owners that when they needed fresh supplies, they would send a man on foot down to the town with the order. Bob would then fly the order out to the mine and deliver it by airdrop. Clarence William Poy, mining engineer and manager of the Bremner lode mine, told the *Valdez Miner* that "parachuting a 1,000-pound diesel engine from an airplane above an Alaskan mine is one of the latest achievements of aviation in assisting the prospector in the pioneer country, to say nothing of dropping dynamite, carbide, canned goods, lumber, drill steel, meat, oil and, in short, everything but eggs into the heart of the frozen North" (1934). Besides the booming mines in the vicinity of Valdez, Reeve Airways—thanks in part to strategic advertising—also picked up increased business from developing mines in the Wrangell Mountains, such as Chisana, Nabesna, and the new gold mine at Bremner, in the isolated Chugach range.

Mudflat Takeoffs and Glacier Landings

The rising demand for business after 1934 also allowed the pilot the opportunity to develop such a distinctive operation that it would quickly manifest into a brilliant reputation and moniker for which he would forever be known. Following trends set by European aviators landing in the Alps, Reeve began flying supplies into mines throughout the Chugach and Wrangell Mountains, landing on makeshift strips near the diggings. Existing in close proximity to most high mountain lode mines were alpine glaciers, where even in summer, winter ruled. Reeve found that, for the most part, the snow on glaciers froze as hard as concrete. He replaced the Fairchild's wheels with wooden skis, instantly making each glacial field a possible landing strip that provided access to the protruding quartz lode deposits.

After a series of trial and error attempts landing on the constantly changing and potentially deadly rivers of ice, Reeve perfected his new niche by paying close attention to the relatively unknown glacial environment. He learned to land in flat light on a featureless glacier by making a preliminary pass while throwing out dark objects, such as gunnysacks dyed black, or willow boughs, anything that gave him depth perception. He also set up flags and sprinkled lampblack to mark the landing area. Reeve learned to identify the location of the mostly hidden crevasses by looking for a slight undulation on the surface, where snow was not quite as blue as the surrounding field. Reeve's rule of thumb: the lighter and drier the snow, the more dangerous on which it was to land. Finally, akin to a hockey-stop, he learned to turn his plane to a 90-degree angle on the slope before cutting the engine so as not to slide backward.

The main problem facing Reeve's innovative glacier flying was that by May, snow on the Valdez airstrip had melted, making it impossible to reach the alpine mines with skis during the warm months of late summer. By winter, when he could finally replace his wheels with skis, the lodes had disappeared with the quickly accumulating snowfall. Reeve, something of a mechanical virtuoso, solved this problem by fixing his Fairchild with stainless steel homemade skis and taking off from the mudflats that fronted Valdez at low tide. But unlike snow, the sticky mud created suction on his skis, making it extremely difficult to get airborne. Once in motion, Reeve had to physically rock the plane in order to tear the skis loose (*Beach 1936*). The hassle proved prosperous, however, for this inventive mudflat takeoff technique allowed him to serve mines year-round. "While other pilots were operating by clock and calendar," recalled Reeve, "I began using a tide book for a manual of operation" (*Day 1957*).

Tourists arriving via steamship often gawked curiously at Reeve's "airport," dubbed "Mudville" by his rivals. Within a year and a half of his arrival, Reeve had developed a reputation as being "intensely competitive" and "fiercely proud of his skill in the air" (*Beach 1936, Day 1957, and Roberts 2002*). Reeve's glacier and mudflat flying skills, besides boosting the mining industry, sparked the imagination of a depressed populace whose collective lives had little opportunity or reason for excitement. Rex Beach wrote several articles promoting Alaska mining that centered on Reeve. The renowned author wrote passionately on his contention that the federal government should invest even more money to create a modern infrastructure for aviation in Alaska. For its efforts, argued Beach, the Territory would attract a fleet of "sky prospectors," who

Reeve Aleutian Christmas Card, courtesy Alaska Aviation Heritage Museum.

Figure 12. Although Reeve's modern airline, Reeve Aleutian Airways, flew passengers throughout the Aleutian Islands until 2000, his "glacier pilot" persona, developed while flying for a brief time in eastern Alaska, remained central to his public identity.

in his mind were "the quickest way to unlock Alaska's golden treasure chest and provide thousands of immediate jobs for young, out of work Americans." (*Beach 1936*).

The End of an Era

By the end of the 1930s, the glacier pilot's "anything goes" approach to flying for the mining industry came to an end as a result of government regulation and the start of World War II. In 1938, the federal government took its first steps to regulate the nation's aviation industry, calling for the establishment of a safe and reliable air transportation system and, for the first time, a distribution of mail contracts. Most significantly, however, the Civil Aeronautics Act established Alaska's first scheduled commercial air routes.

The year 1938 was especially bad for Reeve. After several nationally recognized glacier flying achievements in 1937, a combination of landing accidents, a windstorm, and a hangar fire left him without a plane for six months. This allowed his rivals to monopolize service to Chisana, Nabesna, McCarthy, and Bremner. More significantly, the Civil Aeronautics Board determined outcomes and ultimately granted certificates to a flyer based on the "Grandfather Clause." The clause stated that any pilot or air service that provided regular flights over a given area between May 14 and August 22, 1938, would retain exclusive rights to serve that area from that time on. At the time, Reeve had no planes to conduct business, and therefore, the competitive pilot was ironically squeezed out of Valdez and most of eastern Alaska by an unlucky fluke in the federal law.

But the real hit to aviators like Reeve, whose business depended almost entirely upon the mining industry, was the federal government's reasoning that it made no sense to spend precious resources on further domestic production of the precious metal. Thus, the deathblow for the gold mining industry came on October 8, 1942, when the War Production Board declared gold mining a nonessential industry and ordered most placer and lode gold mining on American soil to cease indefinitely. Faced with uncertainty, the Nabesna and Bremner mines closed, and Reeve moved his family to Fairbanks, confiding later to his biographer, Beth Day, "I was forty years old, with a growing family, one beat-up plane and no future" (*Day 1957*). For Reeve, the decision to leave the Wrangell Mountains was personal, for the pilot was intimately connected to the surrounding mining operations. He owned 846 shares of Yellow Band stock at Bremner and even named his youngest son Whitham, for his friend Carl Whitham, owner of Nabesna mine.

Indeed, the ban on gold mining coupled with Reeve's

Photo from the Russ Dow Papers, courtesy Archives and Special Collections, Consortium Library, University of Alaska Anchorage.

Figure 13. Bob Reeve wearing his trademark rain hat is shown working on his plane, preparing to take off from the Valdez mudflats around 1937. 1937 marked his last year serving mining camps in the Chugach and Wrangell mountains.

departure from the Wrangells marked an end of an era in eastern Alaska. But Reeve, like the rest of the country in 1941, went to work instead of giving up. He left behind his glacier pilot persona to help the United States military transform the Territory into an air bridge, which greatly aided the victorious Allied campaign in Europe and left behind an expanding web of aviation infrastructure that would underpin modern Alaska. After establishing the Northway airfield via Nabesna River, Reeve continued to fly for the U.S. military, helping to establish a chain of air bases in the Aleutians during World War II. When peace came, Reeve had accumulated the experience, as well as enough military surplus aircraft, to conduct a viable air service along the stormy, volcanic island chain. In 1946, he established Reeve Aleutian Airways, which, through his constant guidance, became one of Alaska's most successful and modern airlines, flying passengers over some of Alaska's most hostile terrain until competition and high fuel prices shut down company operations in December 2000. When Reeve died on August 25, 1980, just months before the passage of the Alaska National Interest Lands Conservation Act (ANILCA) converted his old flying territory into Wrangell-St. Elias National Park and Preserve, the editor of the *Anchorage Daily News* reminded readers that men like Bob Reeve carried to Chisana, Nabesna, and Bremner what writers for decades had described as the spirit of frontier Alaska.

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Fire versus Ice: Revolutionizing the Thawing Process at Coal Creek

By Douglas Beckstead

Gold mining is as much a part of the cultural and natural history of Alaska's national parks as any other resource. In fact, in the enabling legislation of several Alaska park areas, gold mining is identified as one of the reasons that Congress deemed these areas worthy of protection.

Gold deposits are found in one of two forms: hard rock where intrusions (veins) extend into the surrounding host rock; and placer deposits where gold bearing rock has eroded and then is transported some distance away from its original location. Deposition in a placer deposit is explained through both simple physics and hydraulics. Gold, with a specific gravity of 19.32, is heavier than the other materials around it so seeks the lowest point in a slurry. (By comparison, lead has a specific gravity of 11.340, silver 10.490, copper 8.940, and iron 7.850.) As a result, when gold-bearing materials erode and are transported downhill by water, the gold works its way down to the bottom and collects at the contact between the bedrock and alluvial gravel (*Spence 1996*).

Figure 1. When thawing operations ceased at Coal Creek the hydraulic pipes were gathered and stacked according to size and use in what is now called the Coal Creek Pipe Yard. The pile of black rubber hoses carried water from the pipes to the cold-water points. The curved goose-neck pieces in the foreground connected the hoses to the points allowing for a smooth flow. In 2011, a wildfire burned through the Coal Creek valley. Burning embers landed on the pile of old rubber hoses, setting them aflame and destroying them.

Douglas Beckstead, 1995

Figure 2: Cold water collected in penstocks on the ditch high above Coal Creek. It then flowed down the hillside through ever smaller pipes thus increasing the pressure. It was then controlled via the gate valves before flowing out to the points in the thaw field ahead of the dredge. These pipes run down the Coal Creek valley near the pipe yard.

Douglas Beckstead, 1995

Figure 3: Cold-water thaw points and valves at the Coal Creek pipe yard. The long sections of pipe in the background are the thaw points. They consist of approximately 10-foot-long sections of 1-inch-diameter pipe with a hardened steel chisel point welded to one end and threads on the other. They were connected to the hoses via a gooseneck (curved) section of pipe. The hoses were then connected to the main hydraulic pipes with the check valves (foreground). These allowed the flow to smoothly move through the circuit.

Douglas Beckstead, 1995

This same process has historically been used to recover gold from placer deposits. The overburden is removed, exposing the alluvial gravels, which are then processed through a mechanical device called a sluice. The sluice uses water flowing over riffles that allow the heavier gold to sink to the bottom while the lighter rocks, sand, and dirt move down and off the stern of the dredge.

Gold dredges mechanize the entire process of recovering placer deposits once the overburden has been stripped away. The giant chain of buckets continually scoops gravel, carrying it upward to where it is dumped into a hopper. From there, gravity and massive amounts of water carry the alluvial gravel down through a trammel that separates the largest rocks from the sand. The finer particles are washed down sluices that separate the gold from the sand. The sand then flows out the tail of the dredge and the gold is recovered during periodic cleanups. Dredges operated at various times on Coal Creek and Woodchopper Creek in Yukon-Charley Rivers National Preserve between 1935 and 1975.

The unique climatic and ecological conditions facing placer miners in Alaska requires them to carry out a complex stripping and thawing process before beginning to work the gold-bearing alluvial materials below. At Coal Creek and Woodchopper Creek, bulldozer operators stripped away the trees, brush, and tundra that formed an insulating blanket over the ground. This exposed a shiny, black surface of frozen muck varying in depth between 6 and 26 feet.

A series of hydraulic nozzles (called giants) sprayed high-pressure water onto the muck. These jets first thawed and then washed away the frozen material. Ernest Patty, the manager of Gold Placers, Inc. and Alluvial Gold, estimated that the summer sun was capable of melting approximately four inches of muck a day. It was then washed away by the water. He further noted that during these operations, Coal Creek, below the stripping area, ran black with the ancient sediments. Within a few weeks, the frozen gravel began to show.

This permanently frozen gravel, or permafrost, was as resistant to the bulldozers as reinforced concrete. During the first operating season (1935), Gold Placers Inc. relied upon steam thawing to prepare the ground for dredging. This process involves driving steam points, sections of one-inch diameter pipe with a hardened chisel point connected to high-pressure steam hoses, into the permafrost. The steam

Photo by Ernest Patty, 1936, courtesy of Douglas Beckstead.

Figure 4: This photograph illustrates the process of driving cold-water points into the alluvial gravel at Coal Creek. Cold water is carried from the ditch high above Coal Creek through the pipes visible in the background. It then flows through the hose, through the gooseneck and down into the vertical pipe that is driven into the ground. The "anvil" is clamped to the vertical pipe after which the sliding "hammer" is positioned above it. By raising and dropping the hammer onto the anvil, the pipe is slowly driven into the gravel. Once frozen ground is reached, the hammer and anvil are then removed and the point man continues the process, moving from one point to the next. The Coal Creek dredge is visible at the left side of the photograph.

escapes through the tip, thawing the surrounding gravel. Over the winter of 1935-36, Gold Placers contracted with several local woodcutters to cut and stockpile approximately 250 cords of wood needed to fire the 40-horsepower boiler they used during the first season of thawing operations (*Patty 1936*).

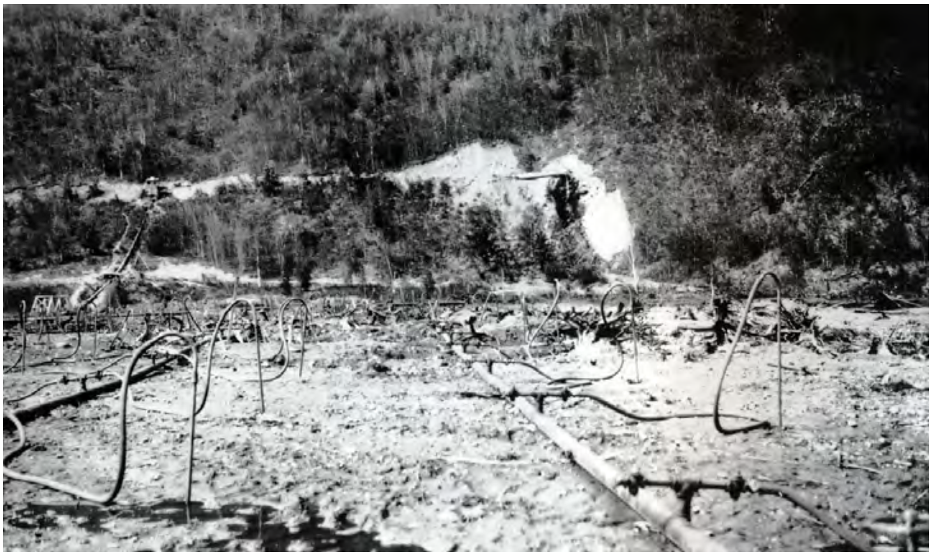
Thawing fell under the jurisdiction of the dredgemaster, Fred Obermiller, based on his years of experience with similar operations at the Fairbanks Exploration Company. When the Coal Creek dredge started working the steam-thawed ground, initial reports called conditions "nearly perfect." This optimism was short-lived when the dredge struck ground that had re-frozen over the winter. Patty noted in the company's first annual operating report that "The steam thawed area embraced 18,000 cubic yards and cost 34 cents per yard . . . and proved worse than useless. This steam thawing, when successfully done, is very expensive and will not be attempted in future seasons" (*Patty 1936*).

When steam thawing proved to be such a failure, Patty turned to a new technique of using cold water drawn from the same ditch that channeled water from Coal Creek used for stripping.

Cold-water thawing is similar to using steam except that, as the name implies, cold water is used. As soon as the stripping crew finished and moved on to new areas, the thawing crew moved in with their lines of hydraulic hoses, pipes, and points. Cold-water points consist of a 10-foot length of heavy gauge pipe, 7/8 of an inch in diameter, with a hardened chisel welded to one end. The upper end is threaded for connecting a hose or additional sections of pipe as the point man, using a slide hammer, drove the pipe deeper into the gravel. Water under pressure flowed through the pipe and slowly seeped into the gravel through two holes on either side of the point. As the ground slowly thawed, the points were driven deeper and deeper into the gravel, continuing the thawing process.

Patty estimated that water flowing into the pipes from the hillside ditch had a temperature of approximately 45 degrees Fahrenheit (7.2 degrees Celsius). When it flowed out of the ground around the thaw points it had cooled to approximately 35 degrees Fahrenheit (1.6 degrees Celsius). Thus, the water transferred approximately 10 degrees Fahrenheit of "heat" to the ground to facilitate the thawing process, all at a minimal cost to the company (*Patty 1969*). By mid-July, sufficient ground was thawed to allow dredging operations to begin. Patty estimated that by the end of the summer, using hydraulic stripping and cold-water thawing, "sufficient ground would be stripped for one or two years ahead" (*Patty 1969; Patty 1935*).

The 1936 season started when the first 250 cold-water thawing points were driven on May 18. Within two weeks, all of them had reached bedrock and were, as Patty noted, "doing good work." An additional 250 points were on hand; however, the flanged feeder pipe to supply them was due on the first down-river boat from Whitehorse on June 5. Unfortunately the White Pass & Yukon Route failed to load them on the first boat although arrangements had been made months in advance. Instead, the pipe was loaded on the steamer Klondike, which sank, taking the pipe with it. The company placed a duplicate order that arrived in late July. In addition, they were able to salvage some of the original order from the wreck (*Knutson 1979*). An additional order of points arrived in August, and a final order for 250 more points that would go into service in 1937 arrived late in the season, providing the company nearly 1,000 points for



Bill Lemm Collection, NPS

Figure 5: Cold-water thaw field on Coal Creek. Water from Coal Creek was diverted near the head of the valley into a ditch that flowed along the west side of the valley. Penstocks, as seen in the background in this photograph, collected the water and transferred it to a system of pipes that ran down into the valley. A combination of decreasing diameter and the height of the ditch increased the pressure. It then flowed through hoses into pipes driven into the permanently frozen gravel where the temperature difference between the cold water and the frozen ground slowly thawed the alluvial gravel. According to Ernest Patty, once ground was thawed using cold water it did not refreeze over the winter, unlike steam-thawed ground.

Bill Lemm Collection, NPS

Figure 6: Gold Placers, Inc. contracted with several men on the Yukon to provide 250 cords of firewood during the winter of 1935-36. This wood was used to fire the large boiler on Coal Creek, which in turn produced steam used to thaw the gravel before it could be dredged. When he realized the high cost of steam thawing, Ernest Patty substituted the use of cold water instead of steam. This change proved much more economically feasible in the long run.

Bill Lemm Collection, NPS

Figure 7: Large water cannons, called “giants,” were used to direct heavy streams of water against the permanently frozen muck that covered the alluvial gravel in the Coal Creek valley. The counterweight of rocks held in the box behind the nozzle allowed a single man to move the nozzle to direct its flow. A small “flapper” at the front of the nozzle allowed the operator to move the giant from side to side.

thawing. Most of these are still in the Coal Creek pipe yard.

Much to the amusement of the crew, occasionally when General Alexander Duncan McRae, the owner of the operation, was at the camp he would walk out and inspect the operations. Several times while crossing the thawing fields, the surface appeared solid when, in fact, it generally had but a frozen crust over the thawed gravel below. On more than one occasion, McRae (he was a rather large man, in stature and girth) broke through, sending him waist deep into the cold gravel and water below. Reports had it that "the boss" always took it in stride and made a joke of it, although it must have been an extremely cold joke (*Lemm 1992*).

Because of the problems associated with getting the points and feeder pipes delivered, there was not sufficient ground thawed ahead of the dredge to operate for the entire season. The dredge shut down on October 5, 1936, a full month ahead of schedule (*Patty 1936*).

Unlike steam thawing, water thawing proved so successful that during the 1936 season, with the exception of the steam-thawed ground that re-froze, the dredge was never bothered by frost in water-thawed gravel. This proved the new method to be reliable and more thorough than the old practice of steam thawing. Its use at Coal Creek was the first in the Eagle-Circle mining district. Gold Placers maintained careful records to enable confident replication elsewhere. The practice was soon adopted in the goldfields around Fairbanks (*Patty 1936*).

The Economics of Dredging

The success or failure of any gold mining operation lies in the economics of how the venture is run. This takes into account not only such tangible costs as equipment, wages, and fuel, but also costs of such things as deposits on containers. During the mid-1990s, the National Park Service undertook a project to gather all of the abandoned drums scattered throughout the Coal Creek drainage. Much to their surprise they did not find any "old" barrels. Almost all of those gathered for recycling were dated to the late 1960s and 1970s. The question was posed of how could the dredging operation from 1935 to 1960 not leave fuel barrels scattered about the landscape?

When the original plans were being laid for purchasing a dredge to work Coal Creek, the Walter W. Johnson Co. stated that the dredge would be powered by two Atlas engines, one to power the digging ladder, winches, screen, etc., and the other to power two pumps. These engines combined would consume approximately 180 gallons (681 liters) of fuel per day. The company engineer, A.P. Van Deinse, recommended that Gold Placers should have a 10,000-gallon (37,850-liter) supply of fuel on hand when the dredge began operation. This would amount to approximately a 50-day supply for the dredge and tractors and would give them sufficient time to have a resupply late in the season that would take them through the end of the season and the beginning of the next (*Van Deinse 1935*).

During the first decade of operation, transporting fuel from Whitehorse to Coal Creek via barges of barrels was not much of an economic hardship. Full barrels were transported down the Yukon and off-loaded at the Coal Creek landing and empty barrels were put back on the barges and taken back to Whitehorse where they were refilled. Between 1942 and 1946 operating costs increased approximately 26 percent while the price of gold remained constant at $32.00 an ounce; it was necessary to find ways of cutting costs to maintain profitability. One of those ways was to cut out the deposits on fuel barrels (*Patty 1946*).

To accomplish this, a decision was made to construct a large oil tank high on the bank above the Yukon slightly downstream from Slaven's Roadhouse (the piping from this tank is still visible today). Fuel was then transported down the Yukon in a large tank on a barge. It was off-loaded and pumped up to the holding tank at Slaven's Roadhouse. When fuel was needed at the camp, a tractor would pull the Athey wagon, the large, tracked wagon that remains at Coal Creek Camp today, down to the Yukon where a smaller tank on the wagon was filled. This was then hauled up to the dredge and the fuel transferred once again. In addition it could be pulled throughout the valley to refill various tractors, etc., as needed. As a result, all of the empty fuel barrels that had been used previously were shipped back to Whitehorse and the deposits refunded to Gold Placers (*Patty 1998a*).

The management of Gold Placers, Inc. and Alluvial Golds continued to make similar attempts to cut operating expenses as inflation continued to rise while the price of gold remained constant. Eventually, by the 1960 season, a decision was reached by Dale Patty and the Board of Directors to close the operation permanently. In Dale's words, "We cleaned up and left. That was October 1960 and the last time I have seen the mines" (*Patty 1998b*).

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Remembering Doug Beckstead

Doug Beckstead passed away at home in Anchorage on July 1, 2014. His dedication to preserve the history of Alaska and the United States will long be remembered by those whose lives he touched and whose accomplishments he recorded. During the 16 years that Doug worked with the National Park Service (NPS) in Alaska he authored the book *The World Turned Upside Down*, a historic narrative of the men and women who worked the gold deposits at Coal Creek and Woodchopper Creek in what is now Yukon-Charley Rivers National Preserve, and began the research for this article. Doug also assisted the NPS Alaska Region's Special Events Team as a commissioned firearms instructor and was assigned on detail to the Anchorage Police Department (APD) during the 1990s, conducting historical research about police officers who had been killed in Alaska and patrolling with APD officers downtown. In 2006, Doug joined the 3rd wing Joint Base Elmendorf Richardson as a military historian, and deployed three times to combat zones in Iraq and Afghanistan to record living history of military operations there.

Photo of Doug from his Facebook page.

Doug Beckstead with Stanton Patty at the Coal Creek Dredge.

Photo of Doug from his Facebook page.

Doug Beckstead

Land Ownership in National Park System Units in Alaska and Possibilities for Mining and Other Developments

By Chuck Gilbert

There are over 54.6 million acres (22.1 million hectares) within the exterior boundaries of National Park System units in Alaska, which is 65 percent of the entire National Park System. Although most of those lands are in federal ownership and are managed by the National Park Service (NPS), there are over two million acres (809,371 hectares) of non-federally owned lands within those units. Passage of the Alaska National Interest Lands Conservation Act (ANILCA) in 1980 created huge new NPS units, greatly expanded three existing units, and included within their boundaries large amounts of non-federal lands. These non-federal lands are in private, state, borough, or municipal ownership. The existence of these non-federal lands creates the possibility of mining and other developments within the boundaries of NPS units in Alaska.

When NPS units are created or expanded, whether by legislation or executive action, they are made subject to any valid rights that exist at the time, and they are also generally closed to all forms of appropriation under the land laws of the United States. So, while no new non-federal lands or land interests can be created within the exterior boundaries of the new or expanded units, whatever non-federal lands existed at their creation or expansion continue to exist. This is the case with all the NPS units in Alaska.

Native Corporation Lands

By far the largest amount of non-federal lands within NPS units in Alaska are lands conveyed under the Alaska Native Claims Settlement Act of 1971 (ANCSA). ANCSA preceded ANILCA by nearly 10 years, so that when the new and expanded NPS units were established by ANILCA in 1980, they were made subject to prior land conveyances to ANCSA Native corporations, and to valid selections by those corporations. Lands conveyed to ANCSA Native corporations are private lands, owned by the corporations. Presently there are 1,462,320 acres (591,779 hectares) conveyed to ANCSA corporations in NPS units, where ANCSA corporations own both the surface and subsurface estates. On most of these lands an ANCSA village corporation owns the surface estate, and the respective ANCSA regional corporation owns the underlying subsurface estate. However, in some situations the regional corporation owns both the surface and the subsurface estates. In addition to those lands, ANCSA regional corporations own 269,142 acres (108,917 hectares) of subsurface estate only, where the overlying surface estate is federally owned and managed by the NPS.

Ownership of the surface or subsurface estates includes the right to use and develop these lands and the resources they contain. The surface estate includes the vegetation, and the rights to use and develop the surface. The subsurface estate includes all resources below the surface, including oil and gas, metalliferous and other minerals, and sand and gravel. In many situations an ANCSA village corporation selected the surface estate, and the regional corporation simply received the subsurface estate beneath the lands conveyed to the village corporation, without regard for mineral potential. But in other situations ANCSA regional corporations selected lands for their potential for mineral development, and have been conveyed lands with potential for oil and gas or other mineral development, such as within Aniakchak National Monument and Preserve, Gates of the Arctic National Park and Preserve, Lake Clark National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Bering Land Bridge National Preserve. A small percentage of lands conveyed to ANCSA regional corporations have restrictions on their use and development, to protect cemetery and historic sites (see ANCSA section 14(h)(1)). Although the ANCSA land conveyance process is now nearly complete, there remain 240,200 acres (97,205 hectares) of ANCSA land selections within NPS

Figure 1. Gold Hill. Unpatented mining claims in Wrangell-St. Elias National Park and Preserve.

NPS photo

NPS photo

Figure 2. Dan Creek. Patented mining claims in Wrangell-St. Elias National Park and Preserve.

units in Alaska, and it is estimated that approximately 180,000 more acres (72,843 hectares) will be conveyed to ANCSA corporations from within those selections.

Land exchanges and purchases that have occurred in NPS units since 1980 have resulted in the conveyance of some ANCSA corporation surface and subsurface rights to the United States, for management by the NPS. For example, the purchase of a 10,000-acre (4,046-hectare) conservation easement around Tazimina Lake in Lake Clark National Park and Preserve conveyed most of the development rights of the ANCSA village corporation (surface) and regional corporation (subsurface) to the United States, effectively prohibiting most developments, including mining, on those lands. Another example is the Anaktuvuk Pass land exchange in Gates of the Arctic National Park and Preserve, which resulted in the conveyance of most of the development rights of the ANCSA village (surface) and regional corporation (subsurface) to the United States, for management by the NPS. Such purchases and exchanges of specific and limited interests in land (for example, the right to construct buildings or the right to extract minerals) require careful review and understanding of the rights owned by both the ANCSA corporations and by the United States, and careful management by the NPS.

State of Alaska Lands

Lands owned by the State of Alaska are the second largest category of non-federal lands in NPS units. The current estimate of state lands within NPS units in Alaska is 355,331 acres (143,797 hectares). These include uplands owned by the State prior to the creation of the NPS units and valid state selections that have been conveyed to the State after the creations. A sub-category of state lands is lands owned by the University of Alaska, whose purpose is to generate income for the University. The State of Alaska also owns road rights-of-way within NPS units, such as the rights-of-way for the McCarthy and Nebesna roads in Wrangell-St. Elias National Park and Preserve, and the George Parks Highway in Denali National Park and Preserve, as well as rights-of-way for smaller roads in several NPS units. The State and the University of Alaska have programs to sell some of their lands, so state lands can become private lands.

The State of Alaska generally owns the beds of navigable waters, such as the Alagnak River, Kukaklek Lake, Nonvianuk Lake, Lake Clark, and the Yukon River. The State also generally owns tidelands. An exception is the tidelands and submerged lands within the offshore boundary of the pre-ANILCA portion of Glacier Bay National Park, which the

U.S. Supreme Court determined in 2005 to be owned by the United States and managed as part of that park, because those tidelands and submerged lands were within a pre-statehood withdrawal that precluded them being conveyed to the state. To date there have been few navigability determinations in federal courts. As additional waters are determined navigable, there will be additional documented acres of state lands. NPS regulations apply to all waters and submerged lands within NPS unit boundaries (36 CFR 1.2(a)(3)).

The state has a process to classify its lands, and to close its lands to the creation of new state mining claims and other uses, as was done on Moose Creek in the Kantishna area of Denali National Park in the 1990s. (Note: whether Moose Creek in Kantishna is navigable has not been formally adjudicated, and therefore the ownership of the bed of Moose Creek has not been conclusively determined.)

Municipal, City, and Borough Lands

There are 1,535 acres (621 hectares) of such lands in NPS units in Alaska. Most of these lands are within Klondike Gold Rush National Historical Park. The City and Borough of Sitka owns some of the tidelands within the exterior boundary of Sitka National Historical Park. The Lake and Peninsula Borough holds some road rights-of-way in Port Alsworth in Lake Clark National Park and Preserve.

Mining Claims

Federal mining claims are created under the authority of the Mining Law of 1872. Although all the federal lands within the NPS units are now closed to staking mining claims, federal mining claims existed on some of the federal lands that were included in the new and expanded NPS units. There are currently 5,669 acres (2,294 hectares) of patented mining claims and 3,992 acres (1,615 hectares) of unpatented mining claims in NPS units in Alaska. Valid unpatented claims give the claimant only the right to mine, not the right to use those lands for other purposes. Patented claims began as unpatented claims but have had all the rights to the land conveyed by United States patent to the claimant. Patented mining claims can be used for any legal purpose, like other privately owned lands. They can be mined; developed for residential, recreational, or industrial use; subdivided and sold; etc. However, mining on both patented and unpatented federal claims within an NPS unit must comply with the provisions of the Mining in the Parks Act of 1976 and its implementing regulations (36 CFR 9A). Under the 9A regulations, a "mining plan of operation" must be prepared by the claimant and submitted to the NPS for review and approval. Mining plans of operation have been approved for claims within NPS units in Alaska. There is currently one approved mining plan, for a block of patented mining claims in Wrangell-St. Elias National Park and Preserve. If the NPS cannot approve a plan, mining cannot occur, and the claims may be "taken" by the United States and the claimants owed "just compensation" under the Fifth Amendment. The 9A regulations apply only to federal mining claims, not to ANCSA corporation lands, other private lands, or state or city lands.

NPS environmental impact statements and Records of Decision for Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve, completed in 1991, recommended that all mining claims in those units be purchased by the NPS, to avoid unacceptable impacts to resources. Thousands of acres of patented and unpatented claims in the Kantishna area of Denali were purchased by the NPS in the 1990s, and few remain there today. Thousands of acres of patented mining claims have been purchased in Wrangell-St. Elias, but 438 acres (177 hectares) of unpatented claims and 5,257 acres (2,127 hectares) of patented claims remain. There are 3,400 acres (1,375 hectares) of unpatented mining claims and 233 acres (94 hectares) of patented claims in Yukon-Charley Rivers; all the unpatented claims on Coal Creek were donated to the NPS, but no claims have yet been purchased in Yukon-Charley Rivers. The last mining claims in Bering Land Bridge National Preserve were purchased by the NPS in 2009.

Native Allotments

The Alaska Native Allotment Act of 1906 authorized the conveyance of up to 160 acres (64 hectares) of non-mineral lands to individual Alaska Natives, for lands they used as residences, seasonal camps, hunting, fishing, gathering, or other purposes. The Act was repealed in 1971, after which no new applications for Native allotments could be accepted. An exception was made for Native veterans of the Vietnam War, who might have missed the opportunity to apply for an allotment between 1969 and 1971, due to their military service. The Alaska Native Veteran Allotment Act of 1998 allowed for the conveyance of Native allotments to qualifying Alaska Native veterans. Because the Native Allotment Act of 1906 allowed for the conveyance of only "non-mineral" lands, if the lands applied for were determined by the Bureau of Land Management to contain valuable minerals, either the mineral rights were reserved to the United States in the conveyance document or those lands were not conveyed to the applicant. There are approximately 52,000 acres (21,043 hectares) of Native allotments in NPS units in Alaska. Nearly all of these lands have now been conveyed, although a few are still in pending or approved status. Native allotments are privately owned and are private property. However, most allotments are in a restricted status, whereby the prior approval of the Secretary of the Interior, through the Bureau of Indian Affairs (BIA), must be obtained for any major change to occur in the status of the allotments, such as a lease, issuance of a right-of-way, or sale. BIA also provides counseling and other services to allotment owners. Native allotments can be developed, like any other private property, but mining development is unlikely because the lands should be non-mineral in character, and if there are minerals, they should have been reserved to the United States, not conveyed to the allotment owner. However, if any minerals, including sand and gravel, or oil and gas, were conveyed to the allotment owner, the owner would be able to legally extract them.

Other Small, Private Tracts

Other small, private tracts include homesteads (up to 160 acres (64 hectares)), home sites, trade and manufacturing sites, and mill sites (up to 5 acres (2 hectares) each). These would have been in private ownership, or validly selected, prior to the creation of the NPS unit. There are 19,127 acres (7,740 hectares) of such lands in NPS units in Alaska. These, too, are private lands, and can be developed for any legal purpose. They generally include all property rights—surface, subsurface, minerals, etc.

Access to Non-federal Lands across NPS Units in Alaska

Section 1110(b) of ANILCA provides that the owners of non-federal lands that lie within NPS units in Alaska "shall be given by the Secretary such rights as may be necessary to assure adequate and feasible access" to their lands, and that "Such rights shall be subject to reasonable regulations . . . to protect the natural and other values." Implementing regulations (43 CFR 36) were put in place in 1986. Consequently, for example, if the owner of non-federal land in an NPS unit in Alaska applies for a right-of-way for a road or an electrical power line across parklands, and the NPS determines that a road or power line is needed to support the owner's use of that non-federal land, then the NPS is required to issue a right-of-way permit for the road or power line, even if there are unavoidable impacts to park resources, and even within designated wilderness. To date, over 30 such authorizations have been issued in NPS units in Alaska, although most have been for existing, not new, off-road-vehicle trails, roads, airstrips, or water lines. As non-federal lands in NPS units are developed in the future, for whatever reason, including mineral or energy development, the 1110(b) provision for access has potential for significant changes and impacts to the NPS units. Careful management is needed to fulfill the Congressional mandate to allow needed access to non-federal lands, but also to protect park resources.

Other ANILCA provisions address access to non-federal lands for mineral development. ANILCA section 201(4)(b-e) (and 43 CFR 36.13) requires the issuance of a right-of-way across the western (Kobuk River) unit of Gates of the Arctic National Park and Preserve, if an application is filed for access to the Ambler Mining District. It is anticipated that an application for such access will be filed in 2014 by the Alaska Industrial Development and Export Authority (AIDEA). AIDEA is planning the construction of an industrial road to access several large copper deposits. The new road would be over 200 miles (321 kilometers) long, of which 12 to 20 miles (19 to 32 kilometers) would be within the preserve. ANILCA sections 11431(j) and 1419(d) respectively, and 43 CFR 36.13, address oil and gas pipelines in the northern portion of Gates of the Arctic, and access through Yukon-Charley Rivers parks for oil and gas operations on ANCSA corporation lands along the unit's northern boundary; no such pipelines or access have yet been proposed.

NPS Regulation of Non-federal Oil and Gas Development

There are no oil or gas operations currently in any NPS unit in Alaska, but there is oil and gas potential in some units. The existing NPS regulations on oil and gas operations (36 CFR 9B) apply to all NPS units, including those in Alaska. Under the current regulations, if an oil or gas operation would occur entirely on non-federal lands (such as ANCSA Native corporation lands where the ANCSA corporation owns both the surface and subsurface estates) within an NPS unit, and no federally owned or controlled lands or waters needed to be crossed to get to that operation, the NPS would have no regulatory control on that operation. But if federally owned or controlled lands or waters had to be crossed to access the oil or gas operation on the non-federal lands, then the 9B regulations would apply and the operator would need to submit a Plan of Operations to the NPS for review and approval. Also, if the oil or gas operation were proposed to occur on ANCSA corporation owned subsurface lands, where the United States owns the surface estate (such as in Aniakchak National Monument and Preserve), the 9B regulations would apply and the operator would need to submit a Plan of Operations to the NPS for review and approval. The 9B regulations have been proposed for revision to provide greater protection to park resources and uses.

Getting Land Status Information

The Land Status Web Map is a great tool for NPS staff in the Alaska Region to view land ownership within NPS units in Alaska (*Venator et al. in this issue*).

The Land Status Web Map displays NPS land status data in the NPS units in Alaska without the use of GIS software. Users can pan around or zoom in and out of the map to quickly view land ownership for a particular area, click on a tract to get more detailed information, run searches to quickly locate a feature, or create a map and export it for saving and printing. This system was designed to be simple and easy to use so that NPS employees around the Alaska Region can quickly find answers to land status questions.

Another valuable resource for lands information in any NPS unit, and available to any NPS employee, is LandsNet, Land Resources Division. On the site you can get the most recent official acreage listings for each NPS unit and region, copies of deeds, the establishing legislation for each unit, published legal descriptions of the unit's boundaries, and much more.

The Land Resources team of the Alaska Region has responsibility for land status mapping and recordkeeping, as well as a variety of other land management and realty tasks and issues. Contact the team with any questions or to get assistance in these matters.

NPS photo

Figure 3. Former placer gold workings, Humbolt Creek, Bering Land Bridge National Preserve.

Tracking Mineral and Energy Development Projects near Alaska Parks through Web Mapping

By Sarah C. Venator, Guy W. Adema, and Marci Johnson

Development History

Alaska is a state inextricably linked to both resource development and wilderness. It includes vast tracts of federally protected land, large and intact natural systems, abundant economically viable resource development prospects, and relatively few residents. Since the late 19th century, visitors have flocked to places like Glacier Bay to experience a connection with the landscape. Yet concurrent with the discovery of Alaska's scenic and wilderness resources, visitors to the state discovered gold and other mineral resources. Development of these resources was instrumental in shaping modern Alaska. A careful balance between conservation and resource development continues today.

The legislative history of Alaska shapes current resource development on Alaska's national park lands. The majority of Alaska's national park units were designated under the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. Many of the lands designated for conservation in ANILCA are adjacent to mineral and oil resources. Additionally, a significant amount of land within park unit administrative boundaries was selected and conveyed to Alaska Native Regional Corporations, including surface and subsurface rights (*Gilbert, in this issue*). Inholders within new conservation units possess certain rights, including development of any valid mining claims subject to National Park Service (NPS) regulation, and reasonable access to private property. ANILCA also made other unique provisions to allow for future development through the new park units; notably, when Congress designated Gates of the Arctic National Park and Preserve, it made allowances for a future road development across the preserve to access significant mineral deposits to the west (*Gilbert, in this issue*).

Many resource development projects within and outside of NPS administrative boundaries of various scales create the potential to affect or impact park resources, either directly or indirectly. Several of these projects would be significant in scale and require major infrastructure development to support their operations, while others are small, and likely or documented to have no significant impact.

The National Park Service has created a database and visual mapping interface that will allow land managers, visitors, and the public to more easily understand the type, scale, and scope of resource development adjacent to parks. The database and map include both the actual development locations and supporting infrastructure such as roads, ports, pipelines, and transmission lines.

Figure 1. The Lik Prospect is near the Red Dog mine. If developed, a connecting road would be built to the Delong Mountain Transportation System.

Background

Since 2010, the Western Arctic National Parklands (WEAR: Kobuk Valley National Park, Noatak National Preserve, Cape Krusenstern National Monument, and Bering Land Bridge National Preserve) have maintained a map of active and potential resource development projects in the region for management use. Decades of mineral exploration adjacent to WEAR are now culminating in proposed road corridors and new infrastructure. WEAR was interested in maintaining the map to allow resource managers to stay apprised of projects and their potential effects on park resources, including subsistence, visitor experience, wildlife populations and migration, and water and air quality. Aside from the 25-year-old Red Dog zinc and lead mine, the vast expanse of northwest Alaska remains relatively pristine.

The WEAR initiative was the basis of the current Mineral and Energy Development web mapping project. Conceptually, the map is a tool to allow park management to track and visualize the various projects by type of development, project activity status, resource type, and other attributes. It will allow users to view broader spatial patterns in projects by attributes of interest. The data will be available in three formats—as a web map; as a story map based on the web map with a more focused thematic approach, text descriptions, images, and links to external resources; and as a database.

Photo by Jim Dau

Figure 2. The Delong Mountain Transportation System is a transportation easement through Cape Krusenstern National Monument to allow shipment of ore from the Red Dog mine to a port.

Photo by Marci Johnson

Fugure 3. The intake building and dam at the Falls Creek Hydroelectric Project, Gustavus, AK.

Geodatabase

The database is the repository of project information, from which the data displayed on the web map and story maps are extracted. It is the most inclusive and versatile in terms of content and capability for data analysis and reporting. On request, the database can be shared with users interested in working directly with the data in ArcGIS.

The type of information captured in the database was determined with input from Alaskan park resource managers and environmental compliance specialists. A set of fields identifies the park resources potentially affected by the project, and the park's level of concern.

Data held in the geodatabase can be broadly divided into information about potentially affected parks and park resources; project timelines and status; project ownership, management, and land ownership; environmental compliance information; external data links; and geospatial metadata. The database can store an image of each project or potential project area, if available.

By nature, these development projects are subject to change. The database maintains a timestamp of each feature's last update date. Links to external resources such as project websites, projects' National Environmental Policy Act (NEPA) compliance websites, and agency websites allow users to keep up-to-date between database updates, and find pertinent information such as open comment periods. Some of these resources, such as the internal NPS NEPA site Planning, Environment and Public Comment (PEPC), may be for internal viewing only and require an NPS login.

Each feature may also have its visibility or reproduction rights restricted based on relevant source restrictions. For example, if a project is in a preliminary planning stage and a park doesn't feel that the available data has been vetted enough to appear on the map yet, it may be omitted. If geospatial data was acquired from an outside source, any associated use restrictions may be included.

Web Map

A web map is a way for users without GIS software to browse and explore GIS data sets and base maps in a web browser. Thematic subsets of data are taken from the developments database, symbolized, and added to maps. Users can pan and zoom on the map, and click on a feature to view a pop-up window displaying its attribute data.

Story Map

Story maps are based on web maps. Story maps enable the viewer to view an interactive map of projects, divided into themes. Unlike web maps, they may contain descriptive sidebars linked to each project, with multimedia and text descriptions of the data for a less technical feel. Links to external resources may be included. This product is the most interpretive and is useful for project summaries.

Resource Development Projects

Approximately 70 resource development projects were identified as being of interest to park management, including dependent infrastructure projects. Of these projects, the owners or operators of 78 percent of the projects have expressed intent to pursue exploration and eventual development, or are already doing so. The remaining 22 percent of projects are inactive, or have been recently abandoned or reclaimed. Approximately 15 percent of projects are already actively producing or in construction phase. Following are two examples.

Example: Red Dog Mine in Cape Krusenstern

The largest active mineral development that has been documented to affect Alaskan park resources, the Red Dog zinc deposit was identified in the 1970s and explored from 1980 to 1981. A road to water was required to export ore; the U.S Environmental Protection Agency determined that an economic impact statement (EIS) would be necessary. The EIS was completed from 1981 to 1984 and concluded that the road option with the least environmental impact passed through Cape Krusenstern National Monument. An agreement was reached between NPS, NANA Regional Corporation, and Cominco (now Teck) in 1986. This road corridor through Cape Krusenstern required congressional modification of the Alaska Native Claims Settlement Act (ANCSA) and an easement through the park conveyed by the Secretary of Interior (*Cocklan-Vendle and Hemming 1992*).

Monitoring in the early 2000s identified that fugitive dust along the road was resulting in deposition of cadmium and lead into Cape Krusenstern National Monument. Subsequently, the mine changed its ore concentrate transportation trailers to reduce fugitive dust, and re-designed its concentrate transfer facility. The mine now has a Fugitive Dust Risk Management Plan and is continuing to work on reducing fugitive dust.

Approximately 15 million gallons of fuel are stored on site near the port. The fuel is transported from offshore tankers. Barges are also used to haul ore concentrates from the port to larger vessels in deep water offshore. However, relative to other activities in the Bering Strait vicinity, the NPS concern for marine activities at the Red Dog mine is low. The mine has the primary response capabilities in the northwest arctic, has a state-approved oil spill response program, and conducts regular response drills.

Approximately 12 miles (19 kilometers) northwest of the Red Dog mine, the Lik Deposit was staked in 1976. Test drilling has delineated an ore body, which the claimant is interested in developing. The Lik Deposit development would be much less economically viable without its proximity to Red Dog. Preliminary plans indicate that the Lik development would share the Red Dog road and port facility, and have lower operating costs by sharing maintenance and port operation fees. Development of

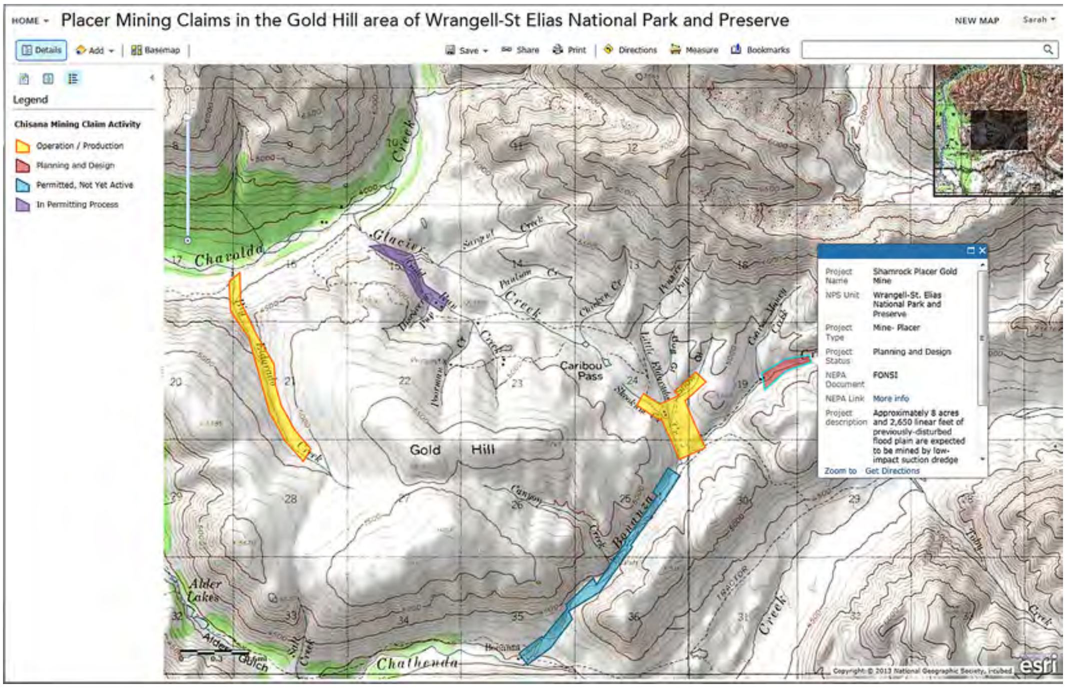

Figure 4. Web maps use select elements of the development database to highlight aspects of projects. This web map depicts ongoing activities on unpatented mining claims in Wrangell-St. Elias National Park and Preserve.

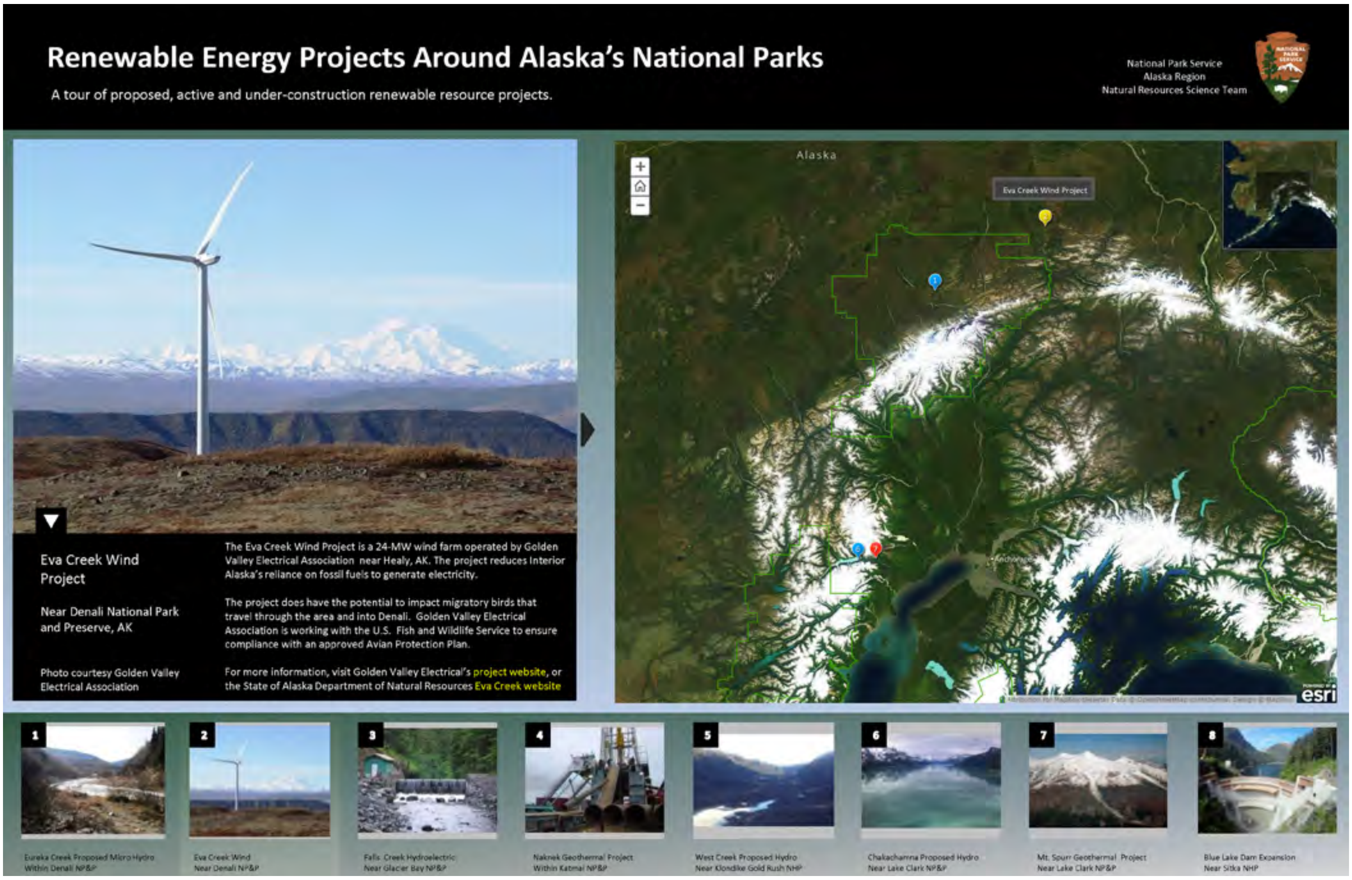

Figure 5. Story maps, such as this story map depicting renewable energy projects near Alaskan parks, are a visually intuitive way for users to navigate information about projects.

the prospect would result in potential increased impacts to the road, expansion of the port, greatly expanded fuel and ore storage capacity, increased vessel traffic, and other necessary growth to support operations (*Matter et al. 2014*).

Example: Mining within Wrangell-St. Elias and Hydropower near Glacier Bay

The Mining in the National Parks Act of 1976 established conditions under which mining can occur within national parks. In Wrangell-St. Elias National Park and Preserve, active placer mining does occur in two areas. In the Chisana district, mining has occurred on some claims for nearly 100 years. Current mining is taking place on previously disturbed areas with relatively low-impact methods.

Other projects, such as renewable energy projects, have been supported by NPS, address climate change, and increase sustainability. One such example is the Falls Creek hydroelectric project near Glacier Bay National Park and Preserve. The Secretary of Interior and State of Alaska agreed upon a land exchange that transferred land from Glacier Bay wilderness in order to build a hydroelectric power plant to supply the community of Gustavus. In exchange, an equivalent acreage of new wilderness was designated in Glacier Bay, and NPS acquired an equivalent amount of land from the State of Alaska within Klondike Gold Rush National Historic Park. This decision involved years of study, an environmental impact statement, and record of decision. The project has greatly reduced the dependency of the gateway community of Gustavus on diesel. Glacier Bay is now investigating ways to connect to the renewable energy resource and reduce its own use of fossil fuels.

Summary

The Red Dog mine is an example of how park awareness of development issues and engagement with regional development projects resulted in a better outcome for park resources. Other projects continue to operate within parks in compliance with NPS regulations and result in no significant impacts to park resources. Continued awareness of activities surrounding NPS units will enable NPS managers to act as better park stewards and more informed neighbors in this largely undeveloped state. This user-friendly database and map allows for easy display and understanding of the scale and scope of resource development near parks.

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What Scenarios May Unfold for North Slope Development and Related Science Needs?

By Dennis R. Lassuy, John F. Payne, and Robert A. Winfree

The North Slope Science Initiative (NSSI) is leading an effort to use scenarios to envision the plausible future story of development on Alaska's North Slope and the adjacent waters of the Beaufort and Chukchi Seas (*Figure 1*). Scenarios will help NSSI to identify the appropriate science strategies to invest in now to better inform management decisions in the future.

The NSSI was collectively formed by federal, state, local, and Native entities in Alaska and formally authorized under the Energy Policy Act of 2005, to serve as an intergovernmental forum for science collaboration. The NSSI is administered through the Bureau of Land Management, a major land resources manager on the North Slope. The National Park Service is an active federal member and has recently chaired the group's governing board.

With over 203,000 square miles (526,000 square kilometers) of land and sea, the North Slope and its adjacent seas are believed to hold some of the largest remaining oil (*Figure 2*), gas, and coal potential in the United States. These areas are also home to a diverse array of fish (*Figure 3*), wildlife (*Figure 4*), and plant resources that support a vibrant subsistence culture. Future development on the North Slope and the Beaufort and Chukchi Seas could be shaped by many forces and many voices. Energy demand and alternative sources, new oil and gas finds, local needs, oil prices, social priorities, food security (*Figure 5*), climate change, international politics—all of these and more may come into play. Key stakeholders will include the communities of the North Slope, energy and resource extraction and related industries, academia, conservation organizations, and the Native, local, state, and federal resource managers of the North Slope Science Initiative.

Photo by Gordon Brower, North Slope Borough

Figure 3. Arnold Brower, Sr. (deceased), former NSSI STAP member, subsistence fishing on the North Slope.

The use of scenarios is an effective exploratory and analytical approach in complex and uncertain situations. "Complex" and "uncertain" are good descriptors for the Arctic and its future. In Alaska, scenarios have recently been applied to questions about marine shipping (*Arctic Council 2009*), climate change (*Winfree et al. 2013*), port site selection, and now energy and resource development.

Scenarios will be used by NSSI in a deliberative and inclusive process that engages these diverse stakeholders in thinking creatively about plausible futures. The NSSI recognized the need for this dialogue and has recently begun a scenarios process as one approach to "Integrated Arctic Management" (*Clement et al. 2013*). The elicitation of development scenarios and an analysis of their potential implications will help prepare U.S. Arctic managers to make informed decisions about the needed research and monitoring. U.S. Arctic managers will need this science to help sustain natural resources and plan for safe energy and resource development in the face of impending changes.

The process will move from scenarios to strategies. All involved will help develop the plausible stories (scenarios) of future U.S. Arctic development. Then we will assess the science needed to understand the implications of each scenario so that regardless of which scenario comes to pass, U.S. Arctic resource managers will be prepared with strategies to collect the appropriate information to make effective decisions.

Early in NSSI's assessment of the state of the science for the North Slope and adjacent seas, its Science Technical Advisory Panel (STAP) and Senior Staff Committee prepared

Figure 1. Northstar production island, Beaufort Sea, Alaska.

Photo courtesy of Bureau of Ocean Energy Management (BOEM)

Figure 2. Trans-Alaska Pipeline.

Photo by Doug Kane, UAF

a series of "Emerging Issue Summaries." Broad topics like sea ice conditions (*Figure 6*), permafrost (*Figure 7*), hydrology (*Figure 8*), increasing marine activities (*Figure 9*), and several others were identified by the NSSI Oversight Group (its governing board), and then questions and specific issues related to each broad topic were developed by experienced agency scientists. The STAP developed the emerging issue summaries through an iterative process that combined input from agencies with information from external subject matter experts.

In compiling these summaries, the STAP recognized a number of "connectivities" (similarities and linkages between the kinds of information required to address science needs across a number of topics). They also published a paper in the journal *Arctic*, in which they laid out a number of "overarching

Figure 4. Caribou form an important part of the subsistence diet of North Slope residents.

Figure 5. Bowhead whale harvest is critical to culture and food security in Barrow and other villages in Arctic Alaska.

Figure 6. Sea ice conditions are changing rapidly in the Arctic.

Photo by Ben Jones, USGS

Figure 7. Warming permafrost and coastal erosion along the North Slope shoreline.

Photo courtesy of USGS

Figure 8. An elevated pipeline crosses wetlands on the Arctic tundra.

Photo by Robert Winfree, NPS

Figure 9. Litering barge transporting ore concentrates.

priorities" (*Streever et al. 2011*). First among those overarching priorities was a "systematic assessment of the range of potential development scenarios" for the North Slope and adjacent seas "in a manner that will contribute to refinement of specific research priorities." The individual issue summaries provided excellent information on the current state of the science and existing information gaps. However, the STAP felt that more was needed in the face of increasing pressure for energy development and a rapidly changing environment. A high priority was an analysis of plausible future conditions to help understand what agencies' future science needs may be and the context in which that science may be developed, undertaken, and used. In short, scenarios were "important for prioritizing and implementing temporally and spatially appropriate research and monitoring."

To address this priority need, a cooperative agreement was entered into in late 2013 between the NSSI and a team formed by personnel from the University of Alaska Fairbanks (with their extensive Arctic and North Slope experience) and GeoAdaptive LLC (a consulting firm with vast experience

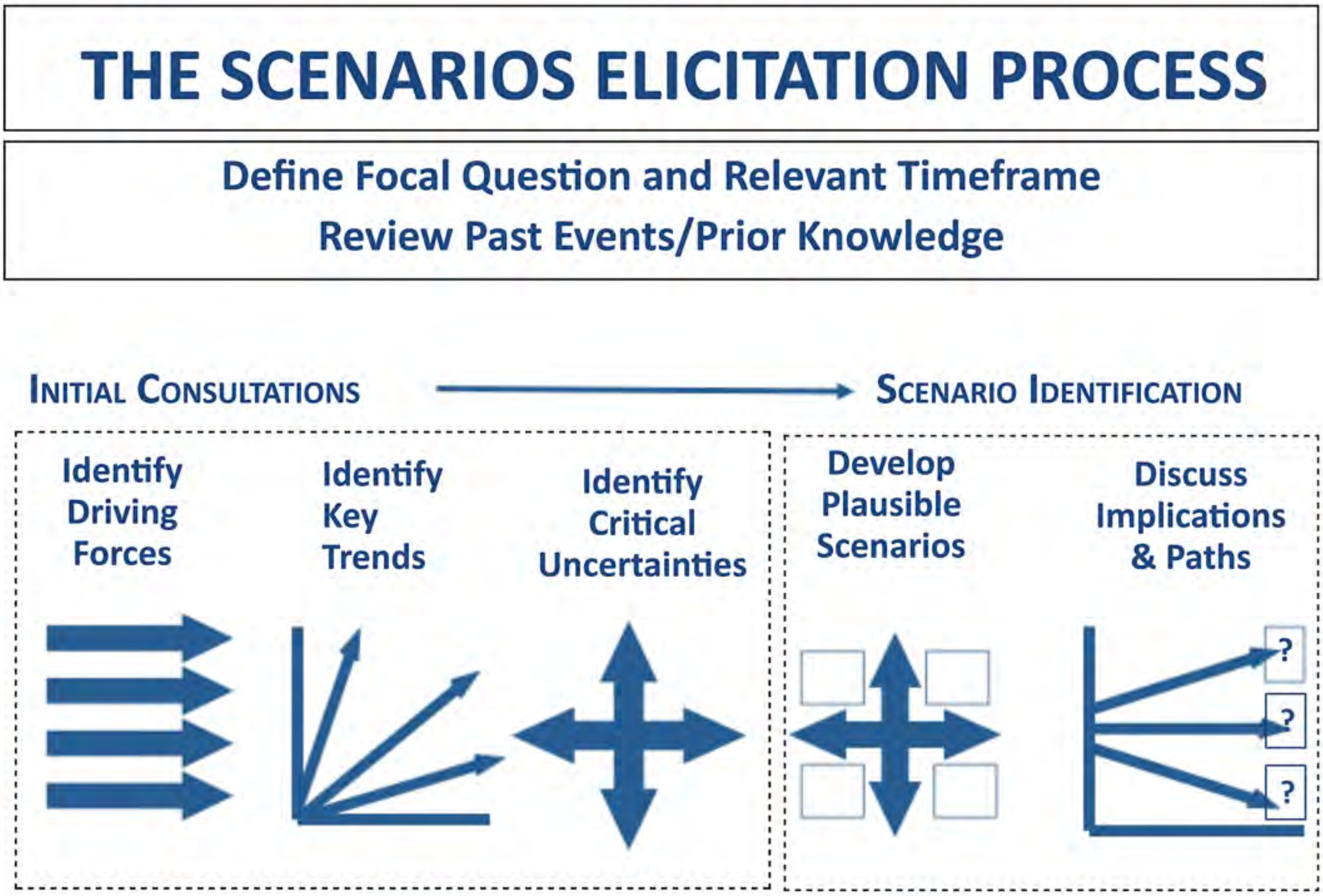


Figure 10. The scenarios elicitation process.

in participatory scenarios projects and geospatial analysis). A flyer, fact sheet, and other materials on the scenarios project are posted at: http://northslope.org/scenarios.

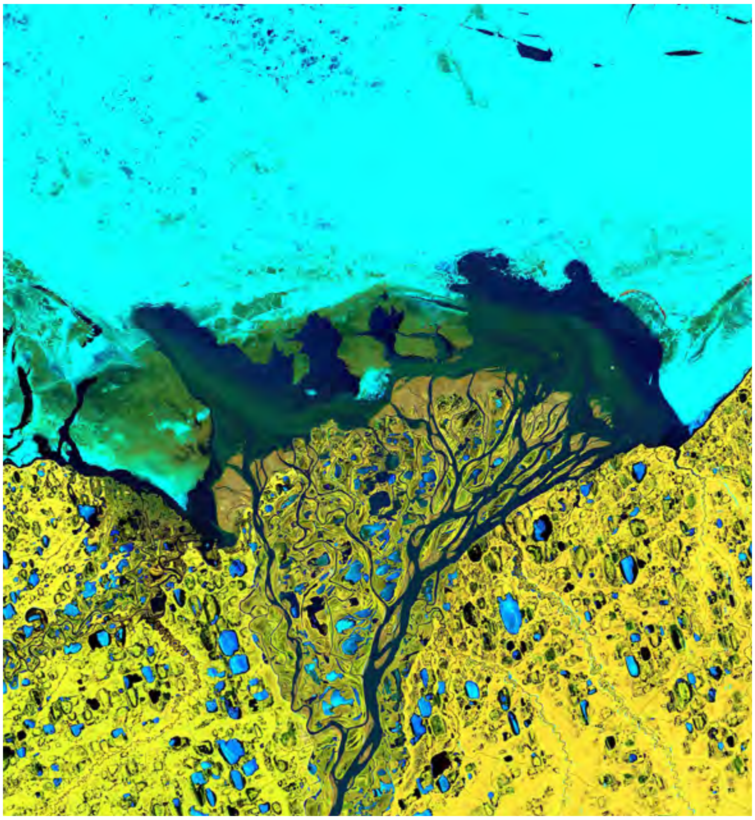
The materials posted on the NSSI website provide some general background on what scenarios are and how they have been used. However, scenarios are basically descriptions of how the future may unfold—often in the form of narratives, accompanied by graphic representations of what each scenario may generally "look like" on-the-ground/in-the-water. The process of developing those scenarios allows us to consider, in an informed, inclusive, and systematic way, a range of potential alternative conditions under which management decisions may play out in an uncertain future.

In order to be realistic in assessing what the shapes of those scenarios may be and which among them are truly plausible, the process is informed by first reviewing and synthesizing current knowledge (building on the past and present to help understand the future) and projections of expected changes (e.g., models). The process is inclusive (gathering input from diverse sources of knowledge and thought) in order to think broadly and help understand the full range of factors that may influence, or be influenced by, the direction of future changes. The process is systematic because it requires that we organize and assess our assumptions, compare and contrast a range of potential drivers of change, and consider the internal consistency of the scenarios that emerge from the analysis. A general depiction of the scenarios elicitation process is presented in Figure 10.

The above description is where many scenario processes stop, leaving the discussion of scenarios and their implications to the involved parties (e.g., companies, agencies, or organizations) to use as they see fit. For the North Slope Science Initiative, however, it's all about the science and being agile enough in our science strategies to be able to inform management decisions under any plausible scenario. The NSSI scenarios project will therefore move beyond this by having a diverse group of scientists and other knowledge holders undertake an analysis of the scenarios and implications that the broader group of stakeholders has produced.

The priority product of this additional analysis is scenario-informed guidance on what kind of research (*Figure 11*) and monitoring (*Figure 12*) will be needed to detect, assess, and respond to the identified range of plausible development-driven changes on the North Slope and adjacent seas. This approach allows decision makers flexibility to monitor and adapt to unexpected events. However, it is also important to consider that one of the most important short- and long-term benefits is that the scenarios process itself can strengthen the level of shared understanding among an involved and informed community of stakeholder participants.

As the North Slope Science Initiative scenarios project progresses, occasional updates and eventual outcomes will be shared in future issues of *Alaska Park Science*. The project is expected to be completed by the fall of 2015.



Courtesy of Ben Jones, USGS

Figure 11. Landsat image of the mouth of the Colville River at break up.

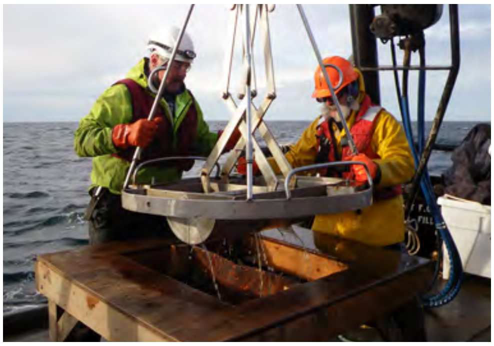


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Figure 12. Coastal ocean sediment sampling under the Alaska Monitoring and Assessment Program.

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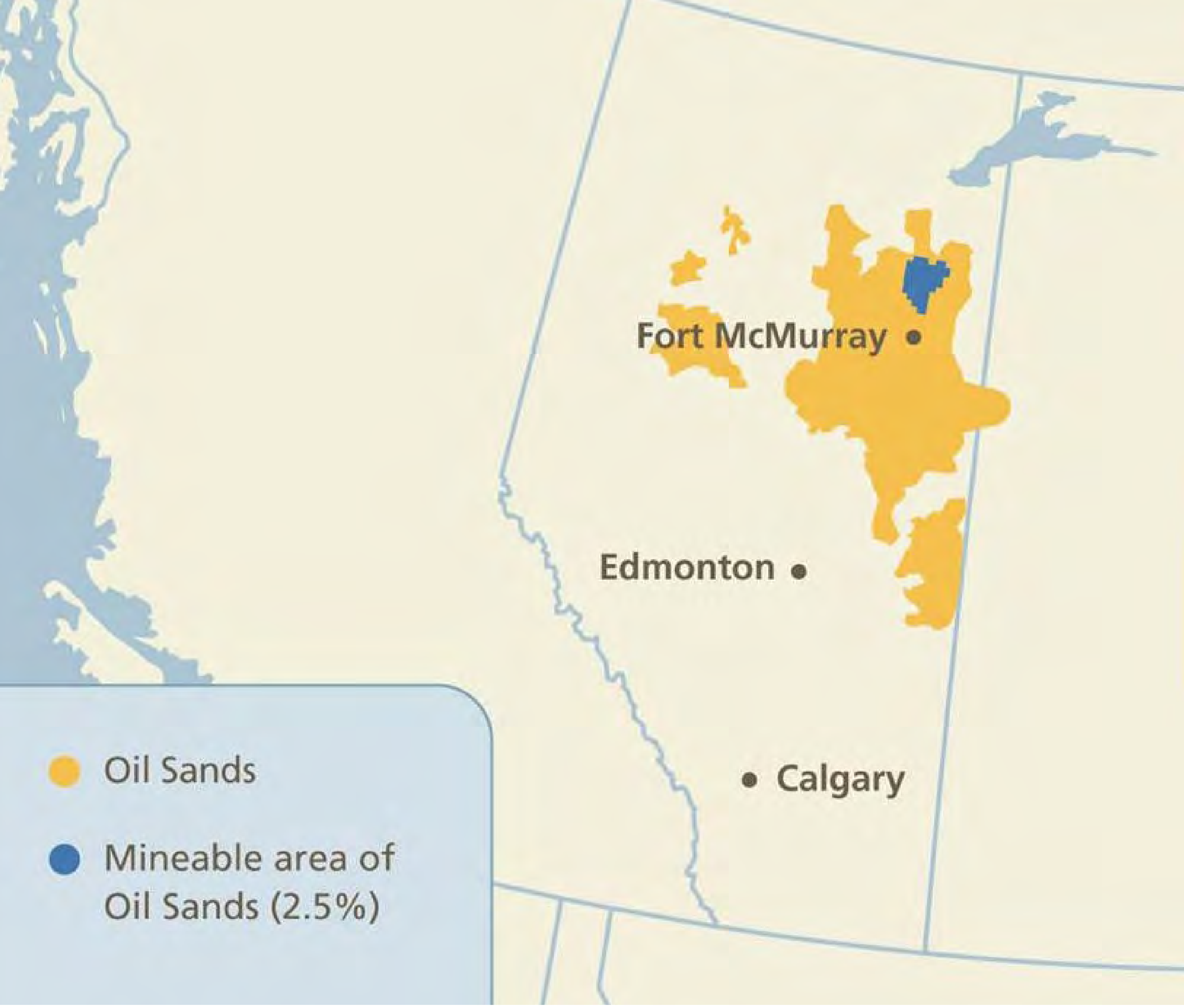
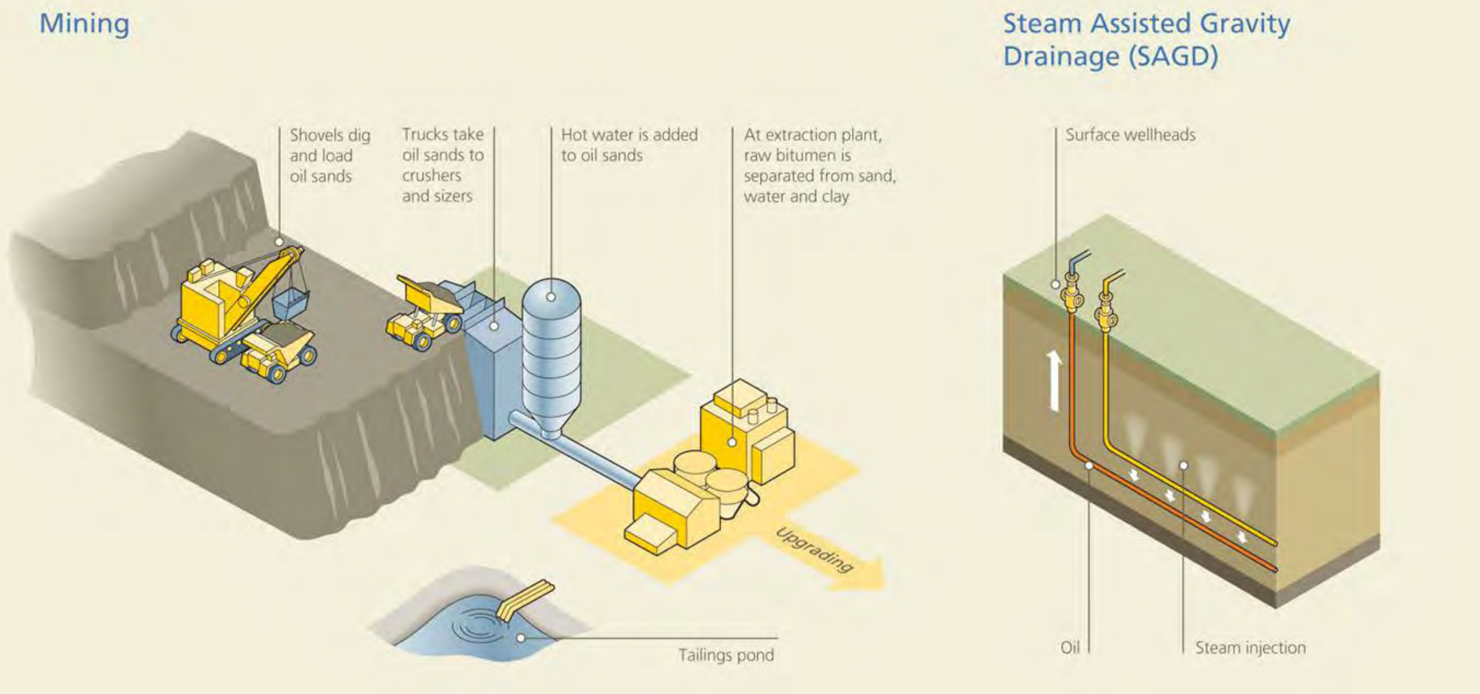

Fort McMurray
Edmonton
Calgary
Oil Sands
Mineable area of Oil Sands (2.5%)


Mining
Shovels dig and load oil sands
Trucks take oil sands to crushers and sizers
Hot water is added to oil sands
At extraction plant, raw bitumen is separated from sand, water and clay
Upgrading
Tailings pond
Steam Assisted Gravity Drainage (SAGD)
Surface wellheads
Oil
Steam injection

Reclamation of Boreal Forest Ecosystems Following Oil-Sands Mining

By Tanya Richens, David Bergstrom, and Brett Purdy

Open-pit mining of oil sands in northern Alberta began in 1967. In the past five decades operational practices in reclamation have adapted to changes in technology and regulatory requirements. One example is the first tailings pond in the region, which was actively used by Suncor Energy from 1967 to 1997. The surface of the tailings pond, now called Wapisiw Lookout, was reclaimed in 2010 to target a locally common boreal forest. It incorporates wetlands and local trees and shrubs, and provides wildlife habitat. The dyke slopes were reclaimed over a period of three decades, during which stakeholder expectations and regulatory requirements changed. Wapisiw Lookout provides an example of how the process of reclamation includes adaptive management to arrive at the final goal of closure and certification.

Alberta's oil sands lie under 54,904 square miles (142,200 square kilometers) of Canada's boreal forest. Only 2.5 percent of this area has deposits close enough to the surface to be mined by truck and shovel (*Figure 1*). Deeper deposits of oil sands are extracted through in situ technologies such as Steam Assisted Gravity Drainage (F*igure 2*).

Oil-sands mining began in the region in 1967 with Suncor Energy (then Great Canadian Oil Sands), followed by the start-up of Syncrude Canada Ltd. in 1978.

Oil sands are a mixture of bitumen (heavy hydrocarbons), water, sand, and fines. A hot-water extraction method is used to separate the bitumen from the sand and fines. The water is stored in tailings ponds to allow the sand and fines to settle out before reuse. Fluid fine tailings remain in the bottom of the pond and settle very slowly. Tailings ponds are a fundamental component of oil-sands mine operations because they facilitate reuse of water in the extraction process.

Pond 1 at Suncor, now called Wapisiw Lookout, was an active tailings pond between 1967 and 1997. As bitumen production increased, the inventory of fluid fine tailings increased, and the tailings pond was enlarged until the dykes rose to approximately 330 feet (100 meters) above the Athabasca River. The tailings pond had a final circumference of approximately two miles (three kilometers). Pond 1, at the end of its life as a tailings pond, contained a large volume of mature fine tailings (MFT). Mature fine tailings are comprised of approximately 70 percent water and 30 percent clay (by weight). These tailings were pumped from Pond 1 to another pond to be treated in a different tailings process, and coarse tailings sand was pumped into Pond 1. Replacement of the MFT with coarse tailings sand allowed Pond 1 to be reclaimed sooner to a terrestrial landscape, supporting progressive reclamation. The treatment of fluid fine tailings to a state enabling reclamation remains a major challenge for the industry.

Figure 1. Distribution of oil-sands deposits in Alberta, Canada.

Figure 2. Commercial technologies in use for the extraction of bitumen from Alberta's oil sands.

Illustrations courtesy of Suncor Energy

Progressive Reclamation

The Environmental Protection and Enhancement Act of the Government of Alberta requires that land disturbed for oil-sands extraction must be conserved, reclaimed, and a reclamation certificate must be obtained. The conservation step requires salvage of reclamation material from the land surface and its storage for use in reclamation at a later date. Because oil-sands mines exist for the most part on public land, the land is ultimately returned to the province after reclamation. The Conservation and Reclamation Regulation states that the objective of conservation and reclamation is to return the land to an equivalent land capability. Land capability is defined in the regulation as the ability of the land to support a given land use, based on the evaluation of the physical, chemical, and biological characteristics of the land, including topography, drainage, hydrology, soils, and vegetation. The concept of equivalency must be considered and evaluated at multiple scales across the entire ecosystem.

The Government of Alberta recently changed the format by which disturbance and reclamation at oil-sands mines are tracked over time. The intent of this change was to provide more clarity for public reporting on the progress of reclamation (*Table 1*). Using Pond 1 as an example, it would have been classified as "disturbed" (used for mine or plant purposes) until 1997, when it would have moved into the "ready for reclamation" category. Between 1997 and 2009, MFT and process-affected water were removed from the pond and replaced with coarse tailings sand (*Figure 3*) to ensure a trafficable surface. A geosynthetic clay liner was used in the cover design of some areas of the pond surface, and swales were included to move surface water to a constructed wetland. From 2009 to 2010 approximately 65,000 truckloads of reclamation material (upland soil, peat-mineral mix, and coarse woody debris) were placed to a depth of 20 inches (50 centimeters) across the surface of the pond (*Figure 4*). Following this

Photo courtesy of Suncor Energy

Figure 3. Pond 1 at Suncor, July 2004.

Photo courtesy of Suncor Energy

Figure 4. Pond 1 at Suncor, June 2010.

Photo courtesy of Suncor Energy

Figure 5. Wapisiw Lookout (formerly Pond 1) at Suncor, August 2012.

activity Pond 1 was moved into the "soils placed" category. In 2010, over 630,000 trees and shrubs were planted, moving Pond 1 into the "permanent reclamation" category.

At this time Pond 1 was named Wapisiw Lookout (*Figure 5*). According to local history, Captain Swan was the name of a Cree Indian who introduced the Hudson's Bay Company to the oil sands in 1719. Swan translates into Cree as Wapisiw. Treaty rights of First Nations and their requirement for a closure landscape that supports traditional practices are important in defining reclamation outcomes. The majority of Wapisiw Lookout is now permanently reclaimed and undergoing reclamation monitoring (*Figure 6*).

Adaptive Management

Reclamation occurs on land that is disturbed over a period of decades, and under successive regulatory regimes. It can be challenging to determine which standards the reclamation will be assessed against at the time of reclamation certification. Perhaps the most significant limiting factor to reclamation is the life-of-mine reclamation material balance. If previous regulatory requirements did not require extensive salvage of upland soils and other reclamation material before disturbance, then it is highly likely that the quantity of reclamation material available in stockpile is insufficient to meet current approval requirements for placement depth. For example, prior to 2007, the typical reclamation material placement depth requirement was 8 inches (20 centimeters) over good and fair substrates. After 2007, this regulatory requirement was increased to 20 inches (50 centimeters). This change left a shortfall of reclamation material for disturbance carried out prior to 2007. Any reclamation material considered as excess prior to 2007 was not salvaged but disposed of with mine waste and irretrievably lost. Although the requirement for reclamation material placement depth was increased by the regulators in 2007, the one parcel of land certified by the Government of Alberta and returned to the province in 2008 was reclaimed to meet the previous 8-inch (20-centimeter) requirement.

Improvements in revegetation practice, wetland construction, and landform design are expected over time. In the mineable oil sands, this evolution of reclamation practice is typically guided by documents produced in a multi-stakeholder forum called the Cumulative Environmental Management Association (CEMA) and recommended to the Government of Alberta. Under CEMA's Reclamation Working Group (RWG), guidance has been developed for landscape design, conservation of reclamation material, revegetation, wetland reclamation, design of end pit lakes, and criteria and indicators for reclamation certification. Moreover, RWG has recently implemented an adaptive management framework, wherein the guidance produced for reclamation will be evaluated on an empirical basis and revised where necessary. This approach is intended to provide assurance that the guidance is delivering the expected outcomes and is supported by a terrestrial long-term plot network.

The following guidance documents have been developed within CEMA, and are currently used by the oil-sands mine operators for planning and operations:

- Landscape Design Checklist (Revised RSDS Government Regulator Version) May 2005 (CEMA-RWG Landscape Design Subgroup 2005)
- Best Management Practices for Conservation and Reclamation Materials in the Mineable Oil Sands Region of Alberta (Alberta Environment and Water 2012)
- Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region, 2nd Edition (Alberta Environment 2010)
- Guideline for Wetlands Establishment on Reclaimed Oil Sands Leases 2nd Edition (Alberta Environment 2008)
- End Pit Lakes Guidance Document (CEMA 2012)
- Criteria and Indicators Framework for Oil Sands Mine Reclamation Certification (CEMA 2012)

Regional Totals for Reclamation and Disturbance Tracking, by Year

	(Hectares)											
Year	EPEA Approved Footprint	Mine Site Footprint	Plant Site Footprint	Total Active Footprint	Cleared	Disturbed: Used for Mine or Plant Purposes	Ready for Reclamation: No Longer Used for Mine or Plant Purposes	Soils Placed (Terrestrial & Wetlands & Aquatics)	Permanent Reclamation (Terrestrial)	Permanent Reclamation (Wetlands & Aquatics)	Temporary Reclamation (Terrestrial)	Certified
2009	134,155	63,285	4,045	67,330	18,395	41,419	913	1,090	3,494	1,158	863	104
2010	135,157	67,836	3,527	71,363	17,047	46,773	394	1,534	3,643	1,192	780	104
2011	136,647	72,504	3,566	76,070	17,050	51,334	250	1,510	3,537	1,150	1,241	104
2012	145,299	80,308	4,085	84,394	20,435	55,902	373	1,447	3,827	1,215	1,227	104

	(Acres)											
Year	EPEA Approved Footprint	Mine Site Footprint	Plant Site Footprint	Total Active Footprint	Cleared	Disturbed: Used for Mine or Plant Purposes	Ready for Reclamation: No Longer Used for Mine or Plant Purposes	Soils Placed (Terrestrial & Wetlands & Aquatics)	Permanent Reclamation (Terrestrial)	Permanent Reclamation (Wetlands & Aquatics)	Temporary Reclamation (Terrestrial)	Certified
2009	331,504	156,380	9,996	166,376	45,454	102,348	2,255	2,693	8,634	2,861	2,133	257
2010	333,980	167,625	8,715	176,340	42,124	115,579	972	3,790	9,001	2,945	1,928	257
2011	337,661	179,160	8,813	187,973	42,130	126,848	618	3,730	8,740	2,841	3,066	257
2012	359,041	198,445	10,094	208,542	50,496	138,137	922	3,576	9,457	3,002	3,031	257

Table 1.

An early guidance document developed within CEMA is the Land Capability Classification System for Forest Ecosystems in the Oil Sands (LCCS), 3rd Edition (*Alberta Environment 2006*). It was originally intended to be a tool for assessing equivalent land capability with a focus on forest productivity. Because of deficiencies in the LCCS that emerged with its use and a shift in focus to a broader set of reclamation outcomes, the LCCS is no longer current. In its place, the overarching expectation for terrestrial reclamation is the return of a locally common, self-sustaining boreal forest ecosystem that includes various types of wetlands. In the past, planting of nonnative trees such as hybrid poplar (*Populus hybrids*), Siberian larch (*Larix sibirica*), and caragana (*Caragana arborescens Lam.*) was acceptable and land use targeted the return of commercially viable forests. The focus now is to use locally sourced seed to re-establish the diversity found in the local boreal forest to return native plant species. Overlapping end land-use targets typically includes wildlife habitat, traditional land use, and commercial forestry.

Even though there were few defined criteria for reclamation in the mineable oil sands when Suncor began construction of Pond 1 in 1967, reclamation of the plateau at Wapisiw Lookout in 2009 to 2010 was considerate of current reclamation expectations. To this end it incorporated the following: drainage design including hummocks and wetlands (*Figure 7*); placement of 20 inches (50 centimeters) of reclamation material; revegetation with native species including wetland species of importance to local First Nation communities; and wildlife habitat including snags, bird and bat boxes, and rock piles (*Figure 8*).

Monitoring Towards Certification

Expectations for final closure are outlined in various sources: conditions of approvals issued under the Environmental Protection and Enhancement Act, reclamation and closure plans developed by the oil-sands mine operators and authorized by the regulator, and various guidance documents produced by CEMA including the Criteria and Indicators Framework for Oil Sands Mines Reclamation Certification (*CEMA 2012*). Further work remains to define

Figure 6. Vegetation assessment at Wapisiw Lookout (formerly Pond 1) at Suncor, August 2013.

Figure 7. Drainage channel at Wapisiw Lookout (formerly Pond 1) at Suncor, July 2010.

Figure 8. Snags installed at Wapisiw Lookout (formerly Pond 1) at Suncor, June 2010.

criteria for, and monitor progress toward, certification.

The assessment of equivalent land capability is typically based on an evaluation of the physical, chemical, and biological characteristics of the land, including topography, drainage, hydrology, soils, and vegetation. It is required that a reclaimed landform be integrated with the surrounding landscape.

Permanently reclaimed landforms may be monitored for 20 or more years before a reclamation certificate is applied for. For example, performance surveys are conducted between 11 and 20 years after planting at sites where commercial forestry is one of the end land uses. Monitoring the effectiveness of reclamation ensures that reclaimed sites are certified only when they meet previously established benchmarks. Effective reclamation monitoring programs need indicators that demonstrate that ecosystem functions are established and plant community composition and structure are developing on an acceptable trajectory to support the end land-use objectives.

Outstanding Challenges

Oil-sands mining is a relatively young industry, with other operators joining Suncor and Syncrude Canada Ltd. in the 1990s and 2000s. The companies have historically worked together with regional stakeholders in forums like CEMA and developed guidance for reclamation through applied research and development programs. Going forward, new organizations like Canada's Oil Sands Innovation Alliance (COSIA) will continue to develop technology to improve tailings management, terrestrial and wetland reclamation, and design of end-pit lakes.

In a region that will be connected by open-pit mines, the spatial and temporal integration at lease boundaries remains a challenge. Management of surface water across the region post-closure and connectivity of wildlife habitat must be considered in project design up front and not just during reclamation and closure. There are still gaps in regulatory expectations at closure, especially for water quality and fluid fine tailings. There is a strong commitment from the companies, regulators, and stakeholders to find the answers and move forward with adaptive management.

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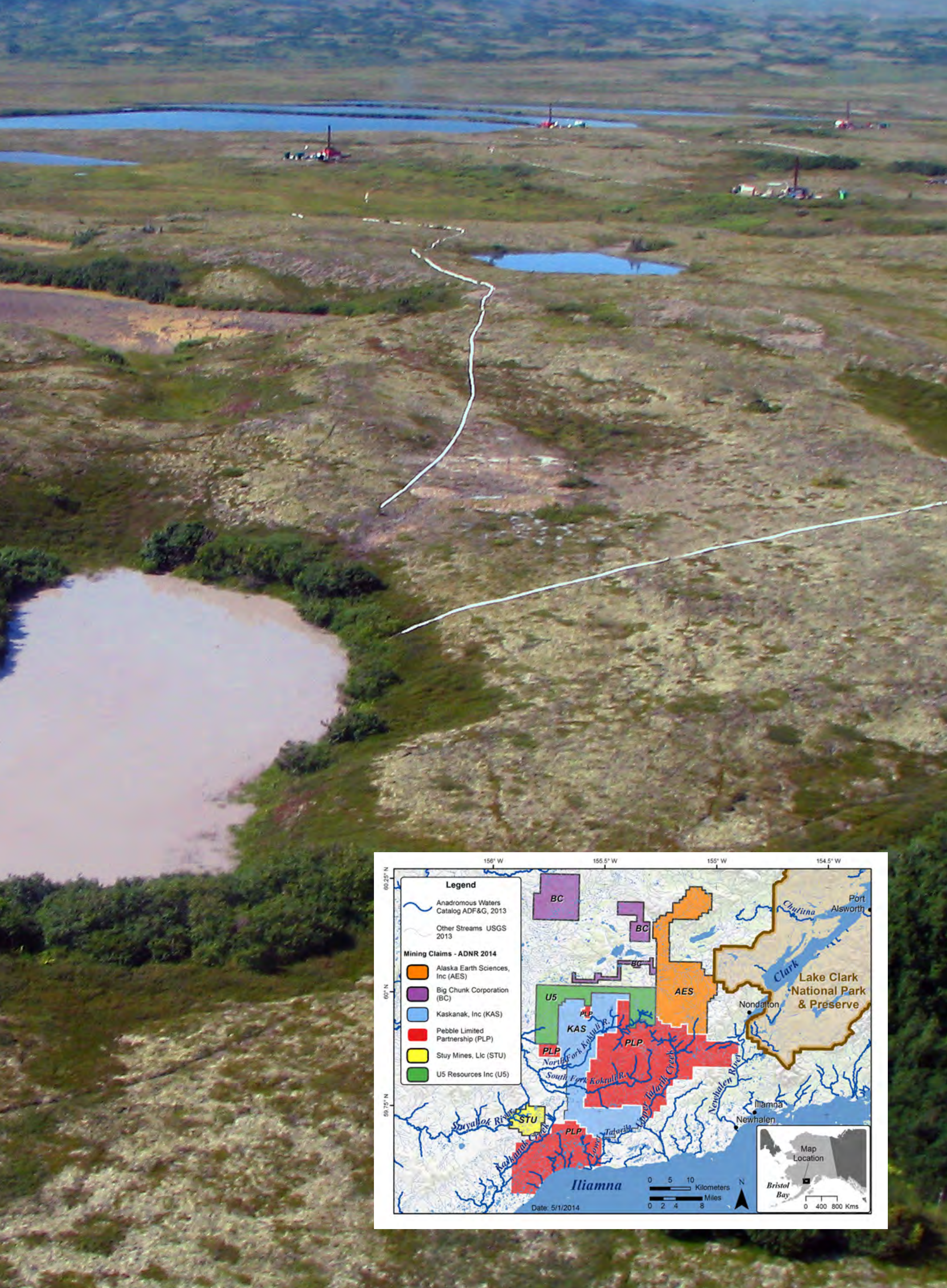

Legend
Anadromous Waters Catalog ADF&G, 2013
Other Streams USGS 2013
Mining Claims - ADNR 2014
Alaska Earth Sciences, Inc (AES)
Big Chunk Corporation (BC)
Kaskanak, Inc (KAS)
Pebble Limited Partnership (PLP)
Stuy Mines, Llc (STU)
U5 Resources Inc (U5)
156° W
155.5° W
155° W
154.5° W
60.25° N
60° N
59.75° N
BC
BC
BC
AES
U5
KAS
PLP
PLP
PLP
PLP
STU
Chulitna
Port Alsworth
Clark
Lake Clark National Park & Preserve
Nondalton
North Fork Koktuli R.
South Fork Koktuli R.
Upper Talarik Creek
Newhalen River
Lower Talarik
Stuyahok River
Kaskanak Creek
Iliamna
Newhalen
Iliamna
0 5 10 Kilometers
0 2 4 8 Miles
N
Date: 5/1/2014
Map Location
Bristol Bay
0 400 800 Kms

Environmental Baseline and Mining in Remote Alaska

By Carol Ann Woody, Sarah O'Neal, Daniel Rinella, Dan Bogan, Dustin Merrigan, and Marcus Geist

Hard-rock mining for metals is an economically important land use. As world population increases so does demand for metals, including copper (Cu); from 1900 to 2012 world refined copper demand increased from less than 0.6 million tons to more than 22 million tons (*ICSG 2013*). Copper is used to conduct electricity and serves important functions in transportation and construction. Although the U.S. recycles approximately 30 percent of apparent Cu supply (*Goonan 2009*), mining is necessary to meet demand (*Figures 1a and 1b*). Most accessible Cu deposits in the Lower 48 and world have been or are being exploited and mineral interest in remote Alaska accelerated during the last decade (*Szumigala 2012*).

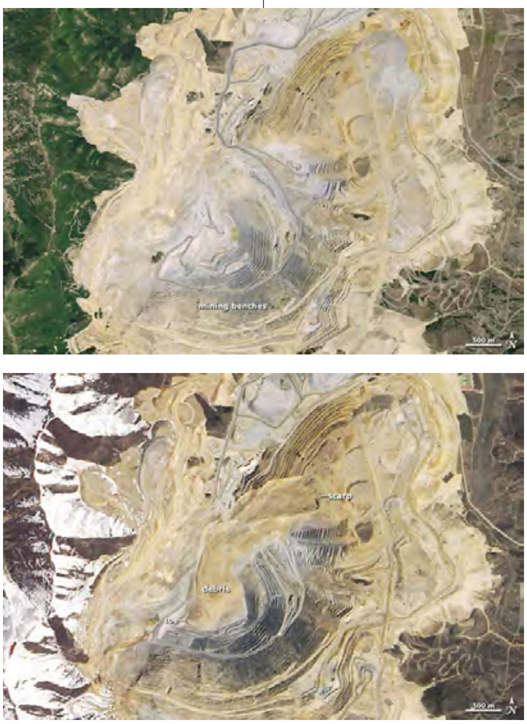

Photo by NASA

Figures 1a and 1b. Satellite view of the Bingham Canyon copper mine, Utah.

Several porphyry Cu deposits are being explored in Bristol Bay, namely Big Chunk and Pebble (*Figures 2 and 3*) in and near drainages to Lake Clark National Park and Preserve (*EPA 2014*). Porphyry Cu deposits are the world's most important Cu sources and are typically low-grade (mean = 0.44 percent Cu in 2008), massive (hundreds of millions to billions of tons of ore), and are mined using open-pit methods (*Figure 1*) (*John et al. 2010*). Potential alterations to aquatic ecosystems from this type of mining include habitat loss, changes in natural water flows, changes in natural water chemistry, and changes in biodiversity (*EPA 2014*). Whereas most porphyry Cu mining occurs in deserts and dry regions with few streams and limited fisheries (*Figure 4*)(*John et al. 2010*), Bristol Bay has a relatively wet climate and hundreds of tributaries feeding six major river systems that support the world's most valuable all-wild salmon fisheries (*Knapp et al. 2013*).

Figure 2. (map) Mine claims in and near drainages to Lake Clark National Park encompass about 750 square miles (1,942 square kilometers). Claims straddle a watershed divide between the Kvichak and Nushagak River watersheds, which comprise approximately 50 percent of the Bristol Bay drainage and produce about 50 percent of Bristol Bay salmon.

Figure 3. (photo) Mine exploration at the Pebble deposit has been ongoing since 1988 with more than 1 million feet (304,800 meters) drilled in over 1,500 drill holes as of 2013 (*AKDNR 2014*). Potentially toxic drill effluent (*Woody et al. 2012*) is legally discharged into unlined sumps, the tundra, depressions, and ponds with no outlet.

Photo courtesy of Bob Shavelson, Cook InletKeeper.

Annual Bristol Bay salmon runs average 38.7 million fish (20-year average, 1991-2010) (*Jones et al. 2012*). Commercial salmon harvests, which began in the 1880s, were recently valued at $1.5 billion and provided 10,000 full-time jobs (*Figure 5*) (*Knapp et al. 2013*). Sport fishing in Southcentral Alaska, which includes Bristol Bay, provided $387 million in income and 12,000 jobs in 2007 (*Southwick Associates Inc. et al. 2008*). Salmon also represent food security and an important cultural heritage to 25 remote, largely Alaska Native communities (*Figure 6*); salmon comprise about 50 percent of their total annual wild food harvest (*Fall et al. 2009*).

Mine claims (*Figure 2*) near Lake Clark encompass about 750 square miles (1,942 square kilometers) and are located in headwaters of the Kvichak and Nushagak River watersheds. These watersheds comprise approximately 50 percent of the total Bristol Bay drainage and produce about 50 percent of Bristol Bay salmon (*Jones et al. 2012*). Concern for aquatic resource conservation increased during 2002-2007 as mineral exploration intensified; by 2007 more than 1,000 exploration drill cores had been drilled in Pebble claims alone (*AKDNR 2013*). Fisheries stakeholders were concerned exploration could alter water quality and potentially harm salmon (*Woody et al. 2012*). However, mine proponents claimed neither salmon nor streams existed in the project area (*Spence 2005, Bauman 2010*). Although three large rivers support salmon in the claims, few tributaries feeding them had ever been surveyed for fish (*Woody and O'Neal 2010*).

The Alaska Department of Fish and Game (ADFG) estimates less than 50 percent of State freshwaters essential to anadromous (sea-run) fish, like salmon, are documented (*Figure 7*) (*ADFG 2014*). However, in order for salmon habitat to receive some protections under The Anadromous Fish Act

Photo by NASA

Figure 4. Much of the world's copper comes from desert regions, primarily the Atacama Desert in Chile, South America. This region receives less than 1 inch (2.5 centimeters) of precipitation a year and some locations have never experienced rainfall.

Category	# Surveys
Salmon	2
Salmon & Resident fish	76
Resident species only	33
No fish captured	4
Dry or no stream course	18
Unfishable (willow, alder, etc.)	4
Total # sites surveyed	137

Table 1. Stream census results in and near Bristol Bay mine claims located in and near drainages to Lake Clark National Park and Preserve, Alaska, 2008-2010.

Photo courtesy of Michael Melford

Figure 5. Bristol Bay commercial salmon fishing provided 10,000 full-time jobs and was valued at $1.5 billion in 2010 (*Knapp et al. 2013*).

Photo courtesy of Michael Melford

Figure 6. Karen Evanoff checks her sockeye harvest in the smoke-house, Nondalton Village, Alaska.

Photo courtesy of Michael Melford

Figure 7. The Alaska Department of Fish and Game estimates that fewer than 50 percent of Alaska's streams have ever been surveyed for fish. If salmon streams are not documented they receive no protections.

Photo by Carol Woody

Figure 8. Example of salmon spawning and rearing habitat in Pebble mine claims that were undocumented prior to this study.

(AS 41.14.870-900) ADFG must "specify the various rivers, lakes and streams or parts of them" important to spawning, rearing, or migration of salmon and record those in the Anadromous Waters Catalogue (AWC) at which point they become subject to regulation (11 5 AAC 195.0110) (*ADFG 2014*). Activities that can disturb or pollute documented salmon streams require an ADFG permit that can regulate activities to help avoid or minimize harm to salmon. Unpermitted activities that harm documented salmon habitat are subject to fines or restoration requirements; water bodies not documented in the AWC are not protected.

By 2008, it was clear that many potential salmon-bearing waters in mine claims were not a priority for fish surveys by the state or mine proponents. Therefore, beginning in 2008 a long-term study focused on wadeable streams of 10 percent gradient or less in and near mine claims was initiated. A 10 percent gradient was selected to stratify the survey effort because stream-rearing salmon generally do not occur in higher gradients (*Figure 8*)(*Bryant et al. 2004*). We focused on a census of likely salmon streams not already documented in the AWC. We selected 137 survey sites in and near mine claims (*Figure 9*), and also established five long-term monitoring sites to sample yearly for water quality, diatoms (algae), macroinvertebrates (aquatic insects), and fish.

We surveyed streams during late August and early September 2008-2010. We fished with a backpack electrofisher (*Figure 10*), which attracts and momentarily stuns fish so they can be easily captured and sampled (*Woody and O'Neal 2010*). Water quality, including temperature, pH, oxygen, and conductivity (ability of water to conduct an electrical charge) were measured. We fished the survey site moving upstream and sampling all habitat types. Captured fish were kept in a bucket of fresh stream water until the entire reach was sampled (*Figure 11*); each reach measured 164 yards (150 meters) long or 40 times the stream width, whichever was longer. We identified and counted fish and then measured all salmon and up to 20 non-salmon. All fish, were released unharmed back to the stream unless we could not identify them; these we took back to field camp to identify.

We visited a total of 137 sites (*Table 1*); four sites were unfishable due to very dense willow or alder, and we did not capture fish at four sites; however, it is important to remember that this single survey is not proof that fish do not occur at these sites, only that fish were not documented

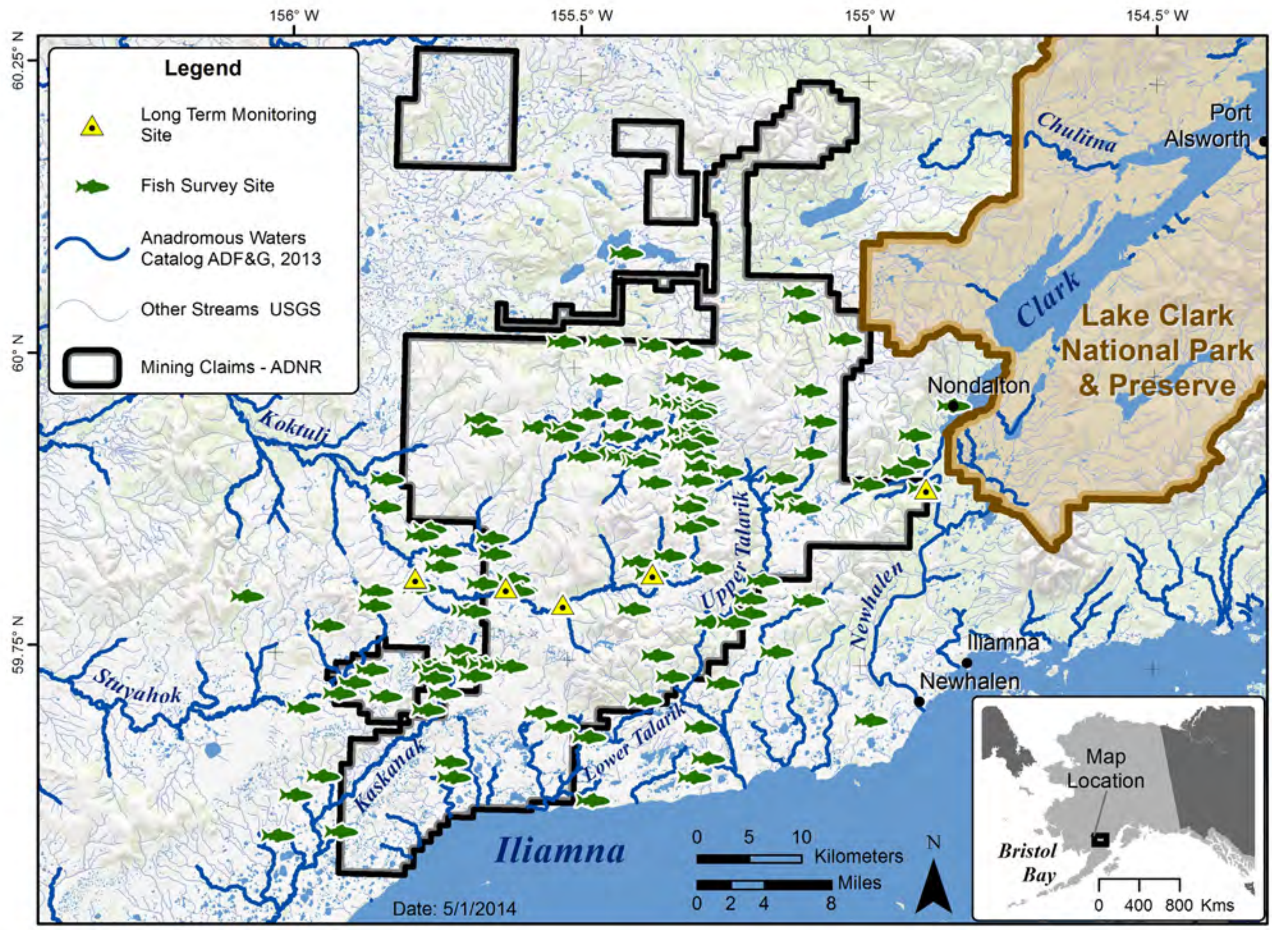

Figure 9. Fish survey sites from 2008 to 2011, and five long-term monitoring sites that have been surveyed for diatoms, macroinvertebrates, and fish since 2008.

Photo by Steve Baird

Figure 10. J. Johnson (ADFG) and Sarah O'Neal (FRC) fish with a backpack electrofisher, which sends a slight electrical charge through the water to attract and momentarily stun fish so they can be easily netted.

Photo by Carol Woody

Figure 11. Daniel Chythlook of Bristol Bay Native Association with slamon, charr, and sculpin captured during an electrofishing survey.

Photo C. Woody

Figure 12. Rearing Coho (top) and Chinook (bottom) salmon documented for the first time in a small tributary of the North Fork Koktuli River.

Photo C. Woody

Figure 13. A rainbow trout captured during surveys contemplates how to escape the measuring board.

during this single survey. They may occur at other times.

We nominated more than 104 miles (168 kilometers) of essential salmon-rearing habitats, mainly small headwater streams, to the State Anadromous Waters Catalog for the first time (*Woody and O'Neal 2010*) including two salmon streams on the Pebble deposit. These streams will now receive increased regulatory oversight and protection if development or disturbance occurs.

In tributaries draining to anadromous rivers, we documented salmon in three of every four streams surveyed (*Figure 12*); resident fish, such as rainbow trout (*Figure 13*) and Dolly Varden, were found in almost every stream surveyed. Surveyed streams averaged 13.2 feet wide (4.2 meters) with a maximum mean depth of 1.5 feet (0.45 meters) and a mean flow of 11.5 cubic feet per second (0.32 cubic meters per second). Waters were cold (mean=47.3 degrees Fahrenheit; 8.5 degrees Celsius), clear (mean=1.9 NTU), neutral (median pH= 7.2) oxygen saturated (mean=98.2%) with very low conductivity (mean=53.1 s/cm) indicating they are susceptible to mining impacts. Collection of robust aquatic baseline data is essential to ensure aquatic resources important to food and economic security are adequately documented, monitored, and protected for future generations should mineral development proceed.

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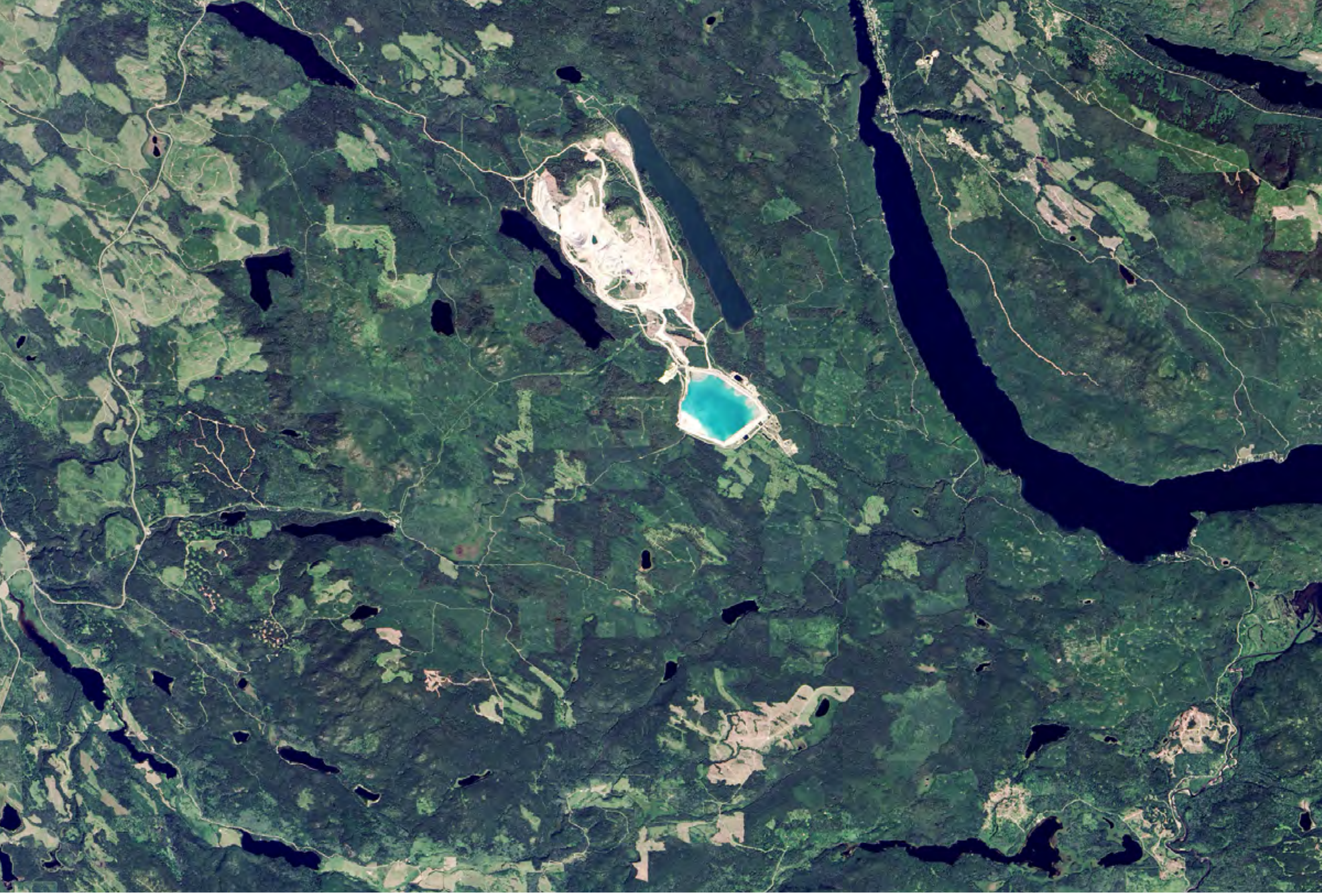


Long-term Risk of Tailings Dam Failure

By David M. Chambers

Large tailings dams, which are built to contain mining waste and are among the largest dams and structures in the world, must stand in perpetuity. Experience shows that a catastrophic release of tailings can lead to long-term environmental damage with huge cleanup costs. The failure rate of tailings dams is also significantly higher than that of water supply reservoir dams. The difference probably reflects two factors: (1) the ability to use construction types for tailings dams that are more susceptible to failure, and (2) the fact that tailings dams are most often constructed in sequential "lifts" over several years, making quality control more challenging than for water supply dams that are constructed all at once. There is a well understood tendency to make assumptions that favor short-term economic situations, and to assume that present technology can and will minimize the long-term risks associated with the design, operation, and long-term closure of tailings facilities. Technology and science have limits, and care must be exercised not to allow the significant economic incentives associated with present day decisions about risk to bias our estimates of the magnitude of these risks to be less, rather than more, conservative.

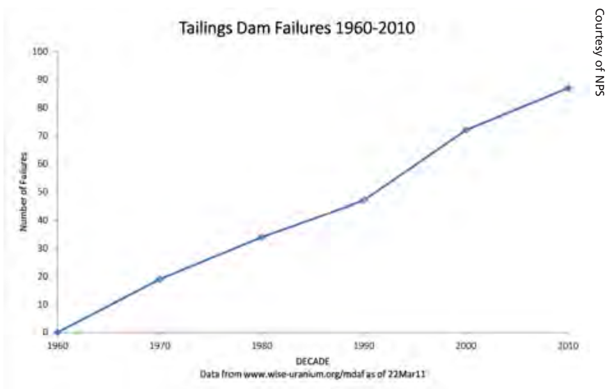


Figure 2. Tailings Dam Failures 1960-2010.

Tailings Dam Failure Incidents

Engineered tailings impoundments have been around for about a century (*MMSD 2002*). The construction and care of a tailings dam is a relatively new phenomenon to society and to mining, which historically disposed of its waste in the most advantageous way, including piling wastes adjacent to the mines and discharging into nearby water bodies. There are more than 3,500 tailings dams located around the world (*Davies 2002*) and between 25,420 and 48,000 large water supply dams worldwide (*WCOLD 2000*). Yet tailings dam failures (events resulting in the escape of tailings and/or water from the tailings dam) have occurred more frequently than water supply dam failures. Even with the obvious requirement for long-term stability, the number of tailings dam failures since 1970 has significantly exceeded the failures for dams used for water supply (*UNEP 1998*).

A catastrophic tailings dam failure can have significant financial and environmental consequences—financial from cleanup and environmental from metals contamination to surface and ground waters, and to soils.

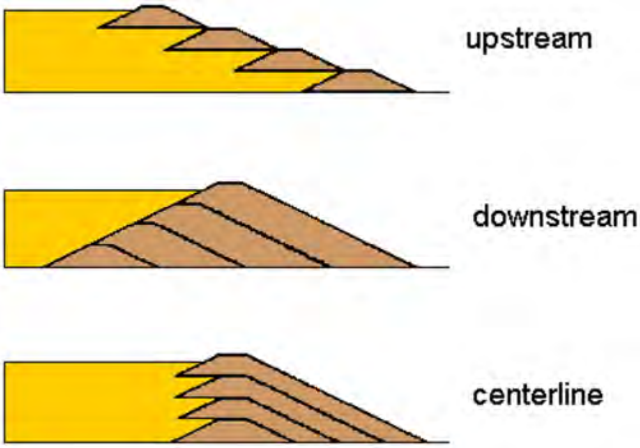
The scale of such consequences is demonstrated by the tailings dam failure at Los Frailes, near Seville, Spain. The dam failure in April 1998 released approximately 528 million gallons (2 million cubic meters) of pyrite sludge and another 1 billion gallons (4 million cubic meters) of acid water containing high concentrations of heavy metals (zinc, lead, arsenic, copper, antimony, thallium, and cadmium) into the Guadiamar River. A 38.5-mile (62-kilometer) -long section of the river, ranging from 0.3 to 0.6 miles (500 to 1,000 meters) in width, was affected. Of the area affected by the accident, 6,560 acres (2,656 hectares) were part of the Doñana Nature Park and 242 acres (98 hectares) were within Doñana National Park. Cleanup costs were in excess of $225 million (€215 million at the 2002 conversion rate) (Arenas and Méndez 2002).

Because of the alarmingly high number of tailings dam failures, the International Commission on Large Dams (ICOLD) convened several studies to investigate tailings dam failures (*ICOLD 2001*). In the 10 years since the ICOLD 2001 report, the failure rate of tailings dams has remained at roughly one failure every eight months, or about three failures every two years (*Figure 2*). Over a 10,000-year lifespan (a figure often used for how long these structures will need to maintain

Figure 1a and 1b. Two NASA Landsat 8 photographs taken one-week apart reveal the massive scope of tailings mud discharges into Hazeltine Creek, Polley Lake, and Quesnel Lake, following failure of the Mount Polley Mine's modern design tailings pond on August 4, 2014. More information on the accident at http://earthobservatory.nasa.gov/IOTD/view.php?id=84202. Image comparison tool at: http://earthobservatory.nasa.gov/IOTD/view.php?id=84202

Photo by Tibor Kocsis

Figure 3. Fish from the Tizsa River in Hungary killed by Baia Mare Mine Tailings Pond cyanide spill.



World Information Service on Energy Uranium Project

Figure 4. Types of sequentially raised tailings dams.

their integrity) (*Wieland 2001*) this implies a significant and disproportionate chance of failure for a tailings dam. One explanation might be the residual effects of outmoded designs and construction practices, but it has been 15 years since the International Commission on Large Dams initiated a major effort to investigate tailings dams and change construction and operational practices, and the rate of tailings dam failures has remained relatively constant.

These dam failures are not limited to old technology or to countries with scant regulation. Previous research indicates that most tailings dam failures occur at operating mines and 39 percent of such failures worldwide occur in the United States, significantly more than in any other country (*Rico 2008*).

Tailings Dam Construction Types

Tailings dams differ from water supply reservoir dams in two significant ways—dam-life design, and dam-construction design.

First, unlike a dam built for impounding water, which can ultimately be drained if the structural integrity becomes questionable, a tailings dam must be designed to safely impound the material behind the dam in perpetuity. This consideration should entail additional design requirements, especially with regard to the seismic and hydrologic events the dam might experience.

Tailings dams are not designed to be free draining after facility closure. For potentially acid-generating tailings it is usually the objective to keep this material saturated after mine closure, because saturation is the best way to limit oxygen and minimize the acid-generation process.

Even if tailings dams were designed to be free draining, it is likely there would be some residual level of saturation (the phreatic level) in the tailings because of their fine composition and low permeability. The residual phreatic level would likely mean the lowest level of tailings would remain saturated. Should the dam fail due to a large seismic event, liquefaction of the lowest level of tailings would probably lead to a large tailings release through a ruptured dam.

Second, while water supply dams are all of the downstream-type construction, the construction of tailings dam can be either (1) downstream, (2) centerline, (3) upstream, or (4) a combination of any of the previous methods.

Downstream construction is the safest type of construction from a seismic standpoint, but is also the most expensive option.

Upstream construction is the least secure because it relies on the stability of the tailings themselves as a foundation for dam construction (*Davies 2002*). Tailings, the ground waste rock from the grinding process, are generally placed behind the dam in water-slurry from the mill, and can remain saturated for long periods. Saturated, unconsolidated material is susceptible to liquefaction under seismic loading. But upstream dam construction, often using the coarse fraction of the tailings, is the least expensive dam construction option, and remains routinely employed in tailings dam construction.

Centerline construction is a hybrid of downstream-type dam construction, and from a seismic stability standpoint the risk of failure lies between that of centerline and upstream types.

Why Tailings Dams Fail

The three leading causes for tailings dam incidents (unexpected events that occur to a tailings dam that poses a threat to dam safety or the environment and requires rapid response to avoid a likely dam failure) are overtopping, slope stability failures, and earthquakes (*ICOLD 2001*). Other long-term failure mechanisms for tailings dams include cumulative damage (e.g. internal dam erosion and multiple earthquake events), geologic hazards (landslides, etc.), static load induced liquefaction (the loss of strength in saturated material due to the buildup of pore water pressures unrelated to dynamic forces—most typically earthquakes), and changing weather patterns (*ICOLD 2001*).

Designing for both overtopping and earthquakes requires a prediction of the largest hydrologic or earthquake event the tailings dam will potentially experience during its lifetime, and in each of these instances the required lifetime is almost always perpetuity. The most conservative design criteria would involve assuming the maximum magnitude of hydrologic and seismic events a tailings dam could experience. Better data, better prediction methods, and employing conservative guidelines for assuming the worst-probable event are needed to remedy these problems. The time periods of concern are many millennia, but the existing seismic data collection is often limited to decades, at best.

Dam incidents in the slope stability, foundation, and structural categories can be largely attributed to

Photo by EcoFlight

Figure 5. Bingham Canyon Mine tailings pond.

Photo by EcoFlight

Figure 6. Chino Mine tailings impoundment in Arizona.

Photo by EcoFlight

Figure 7. Gold Quarry Mine tailings impoundment in Nevada.

Figure 8. Twin Creeks Mine tailings impoundment in Nevada.

engineering design or construction failures. Rigorous design and construction practices, and adopting larger margins of safety in the designs, could address these issues, but tailings dam failure statistics indicate that there are still unresolved issues. Despite a basic understanding of the mechanisms that cause tailings dam failures and a convincing collection of empirical data on the impact of these failures, tailings dams have continued to fail at a relatively constant rate over the last five decades.

Regulatory Framework

The design standards for most tailings dams are overseen by state dam safety agencies. There are no definitive federal regulations governing the construction and operation of metal-mine tailings dams, and only minimal federal involvement in the design of metal-mine tailings dams, usually only when there is a lack of state oversight (*Szymanski and Davies 2004*).

Current standards are focused mainly on water supply reservoir dams, and often lack guidance for tailings dams. The implementation of the standards depends largely on the professional judgment and experience of company consultants and government regulators. The advantage of this approach is that it allows regulatory and site-specific flexibility for tailings dam permits, but it also means that critical assumptions and specifications can vary significantly across similar dams in different locations. For example, one large tailings dam might be designed to withstand a 1-in-2,500-year flood or earthquake event, while a similar structure in another regulatory jurisdiction might be required to design for the 1-in-10,000-year event, which is generally assumed to be the largest possible event (*ADNR 2005*).

Summary

When we consider the recorded life of tailings dams structures (a century at most) compared to the length of time that they must function (millennia), the number of failures observed in the first century of their operation is not comforting. To the author, the statistics suggest a rather severe underestimation of risk continuing even today in tailings dam permitting and construction.

Our society still does not fully appreciate the long-term implications of storing billions of tons of potentially-harmful and semi-fluid waste in large impoundments. Advances to the technology for designing and identifying the long-term threats to these structures have usually been prompted after the fact, by dam failures. Post-failure analyses have identified the need for further analysis, and suggested the need for more conservative assumptions when specifying design requirements and the magnitude of natural events, like floods and earthquakes, that these structures must withstand in the long term (*Szymanski and Davies 2004*).

Policy direction from an organization with responsibilities to guide the safe construction and management of large dams, like ICOLD, tells us that we should be making conservative engineering decisions when designing tailings dams. Yet the failure rates demonstrate that the design specifications for the tailings dams have not always been based on the most conservative assumptions about the source and magnitude of the largest seismic event, and size of the largest hydrologic event, that might be experienced at a dam site. While these decisions may be rationalized in terms of defining reasonable risk, we must also acknowledge the very real pressure of present day economic costs to builders of the dam, if we are to lessen the assumed magnitudes of risk associated with the design of a tailings dam.

Making reasonable rather than conservative assumptions may increase the long-term risk to the society that will inherit the dam and the responsibility for managing the waste, and any future costs associated with the escape of impounded waste due to an unanticipated event. The potential for an unanticipated event should drive our initial design assumptions to be more conservative, not less.

Other recent events, such as the Gulf of Mexico oil spill, also demonstrate that we don't fully appreciate the potential risks and consequences of some industrial hazards. The 2011 Honshu, Japan, earthquake released eight times as much energy as the maximum earthquake estimated by seismic risk experts (*CIRES 2011*) and caused a tsunami that crippled the Fukushima nuclear reactors. Our technology and science has limits; greater consideration should be given to those limits and a precautionary attitude adopted when making present-day decisions about difficult-to-estimate magnitudes of risk.

Figure 9. On August 4, 2014, a catastrophic dam failure occurred at the Mt. Polley mine in British Columbia. At this writing the exact cause of the dam failure has yet to be determined, but the impacts to the stream below the dam are significant. More information on the accident at http://flip.it/4s05M. Photo by Chris Blake courtesy of MiningWatch Canada.

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Abandoned Mine Lands in Alaska National Parks —An Overview

By Linda Stromquist

Introduction and Background

Abandoned Mine Lands (also referred to as Abandoned Mineral Lands, or AMLs) are disturbed lands altered by the operations conducted in search of minerals at surface and underground sites. AMLs include sites and features associated with hard-rock, placer, and dredge mining; gravel pits, rock quarries, oil and gas exploration and development; and geothermal sites.

The wide variety of mining processes employed in search of valuable mineral commodities has made for fascinating study in the 49th state. From the Klondike Gold Rush that spread to the Yukon, to more recent gold discoveries, such as the beach placers of the Nome coast, evidence of mining is found throughout the history of the state and the Alaskan parks.

In the far north, placer mining of permafrost and hard rock mining resulted in a scattering of abandoned mine features that have deteriorated in the harsh climate, leaving many naturally reclaimed. In Denali, the Kantishna mining district comprises dozens of mining efforts representing various eras and stages of mining operations, both from hard rock and placer mining techniques. Hard rock mines are abundant in the mountains of Wrangell-St. Elias, with recognizable features that are found in many other parts of the country. Beach placer deposits have been staked along Alaska's extensive coastline in several episodes of frantic activity. Interior Alaska saw both placer and hard rock mines for metals and coal. The large bucket-line dredges that once plied the frozen ground of numerous drainages of the Yukon River country are representative of the industrious nature and fortitude of the Alaskan miner. These sites represent the mystique and lore of the hardy individualists that explored and settled the Alaskan wilderness, and provide visitors with a tangible connection to the heritage preserved by these sites.

Figure 1. The Kennicott Mill building is an example of an attractive but extremely hazardous feature.

NPS photo

These sites also preserve many safety and environmental hazards that visitors unfamiliar with mining operations may not recognize as hazards. Examples of these hazards are numerous and include crumbling structures, failing portals, open shafts, and structures clinging precariously to cliffs that represent extreme falling hazards.

The remote location of these features intensifies the seriousness of injury that can occur at these sites, which are often the intended destination in a region of roadless wilderness. Additionally, as part of the history of Alaskan settlement, many sites have interpretive displays or information for park visitors, highlighting the interest in these features.

From the thousands of mining claims that existed at the time of the establishment of the Alaska park units, several hundred still remain within park units, leaving many abandoned sites and features in various stages of disrepair and failure scattered throughout the parks. There are approximately 750 of these abandoned mine features on National Park Service (NPS) lands in Alaska.

Initial AML Program Efforts

Since 1981, the NPS Alaska region management has worked to quantify the number and type of hazards posed by these sites and has pursued a variety of solutions to mitigate the issues presented by relic mining features. Initial efforts beginning in the late 1980s, in partnership with the State of Alaska AML Program, and the Office of Surface Mining, instituted closure of a number of mine entrances utilizing polyurethane foam methodologies, and the installation of lightweight steel gates.

Following these efforts to mitigate the most serious immediate safety hazards, beginning in 1991, and continuing through 2010, agency staff identified mining-impacted landscapes for restoration projects that resulted in large-scale mitigation and reclamation of the effects of mining and associated mine workings. Numerous drainages in Denali, Gates of the Arctic, Yukon-Charley

Rivers, and Wrangell-St. Elias parks were part of a multi-year effort to remove mining debris, including thousands of empty fuel drums and non-historic trash.

Landscape restoration activities at Kantishna in Denali (*Adema et al. 2011*), and the soils mitigation project at Coal Creek in Yukon-Charley Rivers (*Stromquist 2005*) are examples of reclamation projects undertaken by NPS during this time period. These projects restored altered riparian zones by re-establishing natural drainage patterns and vegetation, and mitigating contaminated soils associated with past mining activities.

ARRA Funding: the Next AML Phase

NPS AML management received a boost when congressional set asides through the American Recovery and Reinvestment Act (ARRA) in 2009 and 2010 provided funding for the mitigation of known high-risk physical safety hazards at mine sites service-wide, the direct result of a Department of Interior audit of management of AMLs. With these funds, Alaska region program managers aggressively tackled a backlog of known safety issues and mitigated hazards at numerous locations throughout the Alaska parks.

NPS photo

Figure 2. Coal Creek bucket-line dredge is a popular visitor attraction.

In Alaska, a large component, and the highest priority, of AML hazards removal has been abandoned explosives mitigation. Abandoned explosives include blasting caps, dynamite, explosive materials, and blasting fuse and cord, all which have been found at many AML sites throughout the parks. Removing or neutralizing explosives was carefully conducted by NPS staff, as the Alaska region was fortunate to have a trained and certified blasting officer for many years. These hazards were safely disposed of prior to additional inventory and assessment work by park staff. To date, the NPS has safely mitigated 2,188 blasting caps, 3,653 pounds (1,657 kilograms) of dynamite, and 9,805 feet (2,989 meters) of blasting fuse from sites throughout the region.

In addressing other sites on the backlog list, and prior to initiating mitigation and closure, site visits were required to inventory the entire mine site and record feature-specific measurements. The sites were also surveyed for cultural resources documentation and determination of historic value. These data informed project compliance and formulation of project plans and logistics.

Selection of closure type must consider accessibility, stability of the feature, the geologic conditions on-site, necessity to maintain water or air flow, wildlife concerns, cultural resource preservation, and numerous other site aspects. The site-specific data were used to adaptively design closures for sites with clearly identified hazards utilizing proven technologies. The most common mitigation and closure techniques that have been employed at Alaska sites include:

- Warning signs illustrating hazards at abandoned mine sites and prohibiting access. Signs are frequently the first response measure prior to more permanent closure methods.

NPS photo

Figure 3. Another falling hazard is old mine structures perched on the edge of mountain sides.

NPS photo

Figure 4. Open shafts are extremely hazardous.

NPS photo

Figure 5. The Monarch Adit at Glacier Bay National Park and Preserve is an example of a very dangerous mine portal.

- In some locations, where natural deterioration and partial failure of the mine opening has occurred, the collapse and closure has been facilitated by staff using hand tools and controlled blasting.

- Polyurethane foam (PUF) plugs with a surface cap of native materials have been one of the more frequently employed closure mechanisms in the Alaska park units. PUF components can be transported relatively easily to remote sites, where combined, the foam expands up to 30 times its original volume and sets up quickly, even in the cooler temperatures of many mine sites in Alaska. Foam plugs are used when site conditions at the portal or opening are not stable, or competent, and there is no reason to maintain access.

- Steel gate closures (often made of manganol) may be installed with lock mechanisms to allow access. Steel gate closures are used in situations where the portal walls are stable and competent, allowing installation of rock anchors to which gate components are welded. Gates are used to allow for interpretive purposes and monitoring and sampling of the site, as well as to provide for wildlife passage, such as bats and small mammals.

Once installed, all closures must be routinely monitored for damage caused by wildlife, vandalism, corrosion or failure of materials, and natural processes such as subsidence and weathering.

AML Inventory Project

NPS managers recognized that the ARRA funds were insufficient to deal with the magnitude of the AML issue on NPS lands. As the ARRA projects neared completion, a new service-wide inventory effort was established. The goal of this project was the systematic and comprehensive inventory and assessment of all AMLs on National Park Service lands, to identify site-specific human health and safety hazards associated with AML features, and to prioritize and create cost estimates for mitigation of these issues.

The timeframe for the ambitious project was 2010-2012. Research and fieldwork to accomplish the goals of the project began in October of 2010, following completion of the ARRA projects. Mine sites and features in parks were researched online through mining records and through park reporting methods. These sites were compiled and assessed for hazards, stability, and future mitigation requirements. Site visits were prioritized in alignment with previous AML program procedures, which identified as the highest priority those sites reported to have abandoned explosives, followed by sites with known or suspected open underground workings, or hazardous materials such as chemicals or petroleum products.

The limited timeframe with respect to the scope and schedule of this project necessitated access to several sites through the use of helicopter-based operations. Many locations in Glacier Bay National Park and Yukon-Charley Rivers National Preserve were accessed through boat-supported operations. Logistical support costs for these

NPS photo

Figure 6. Explosives found in adit in Wrangell-St. Elias National Park and Preserve.

NPS photo

Figure 7. Warning sign at Lakina Adit in Wrangell-St. Elias National Park and Preserve.

NPS photo

Figure 8. Helicopters help in the logistics for bringing closure supplies to mine sites.

NPS photo

Figure 9. Polyurethane foam (PUF) closure with native materials.

efforts were a large portion of the overall project expense.

In Alaska, this comprehensive inventory was conducted by specifically trained NPS staff from the regional office in conjunction with resource specialists at the parks. Due to the expense of returning to these remote sites, NPS staff ensured that newly discovered safety threats such as explosives and obvious physical hazards were secured while the inventory team was onsite.

Numerous sites surveyed during the course of this project represented the first site visits by NPS employees in decades and provided information for eligibility determinations to the National Register of Historic Places. The inventory of the Alaska park units resulted in capturing data and documenting the status of 751 sites. Final data was reported to the AML database in December 2012.

With the information in hand from the conclusion of the comprehensive inventory, NPS management now has a clear understanding of the magnitude and scope of AML issues in the service. At this time, 54 of the most hazardous and easily accessed openings into abandoned mines in the Alaska parks have been physically closed to visitor access. Although no injuries or fatalities are known to have occurred at abandoned mine sites managed by the NPS in Alaska, many Alaska sites are near airstrips developed to support past mining activities. Those airstrips are frequently used now as backcountry drop-off points for hikers and visitors eager for remote wilderness experiences. The simple fact that the only access through a wilderness area may be along the vestiges of a 100-year-old road leading directly into abandoned mine workings weakens any suggestions that such sites pose less danger because they are so remote. While sheer remoteness could reduce the frequency of potentially hazardous encounters, the probability of delayed medical response means that injuries occurring in remote locations are more likely to become life- or limb-threatening.

Current Status of AMLs

Approximately 28 features in the Alaska park units were identified as high priority for mitigation by the recent inventory conducted for the NPS comprehensive AML report (*Burghardt et al. 2013*). The continued focus of AML program managers will be to resolve safety issues at these sites, ensure that mining-impacted landscapes are reclaimed to restore natural processes, and to preserve cultural resources and wildlife habitat. These abandoned features provide an opportunity to promote thoughtful perspectives of mining artifacts by informing and educating park visitors not only of the hazards, but also the significance and place in the landscape of our mining history.

NPS photo

Figure 10. Welding a gate.

NPS photo

Figure 11. Helicopter survey of cliff adits.

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State of Alaska's Abandoned Mine Lands Program

By C. Justin Ireys

The federal Surface Mining Control and Reclamation Act was signed into law on August 3, 1977, to regulate surface coal mining and reclamation nationwide. In May of 1983 the State of Alaska took primacy of the Abandoned Mine Lands (AML) program and for the past 31 years has been working in all corners of the state to reclaim abandoned mines.

Land and water that are eligible for the reclamation are those that were mined or affected by mining and abandoned or left in an inadequate reclamation status prior to the law passing in 1977. AML funds can be spent on coal and non-coal abandoned historic mines. State, private, Alaska Native, and federal lands are eligible.

The fee collection that provides the funds that the federal government distributes to the various states and tribal entities has been extended by Congress until September 30, 2022. The AML Program is funded 100 percent by the AML Trust Fund, which is administered by the federal Office of Surface Mining Reclamation and Enforcement; there are no state general fund dollars used in the AML Program. AML funds are collected from a fee assessed on today's coal industry for every ton of coal produced and used to correct past deficiencies on now-defunct mine sites. The fee is 28 cents per ton for surface mines and 12 cents per ton for underground mines.

Alaska is considered a Minimum Program state and has been funded at the Minimum Program level since 1994. The grant amount for Minimum Program states is currently set at $3 million annually. These funding levels will remain constant until 2022, although it is important to note that AML's annual grants are subject to federal sequestration.

Inventory and Accomplishments

Alaska's coal and non-coal abandoned historic mines were broadly inventoried in 1983, and 340 sites were identified. Coal mining in Alaska has been well documented and every mine of significance has been identified.

Every inventoried site was evaluated to determine if it qualified for AML funding. Federal policy requires that priority one and two coal projects (the most likely to cause death or severe injury to site visitors) be completed first.

Figure 1. There are various methods for closing dangerous mine openings.

Photo by C. Justin Ireys

Priority three coal projects (environmental issues) can be completed in conjunction with priority one and two projects or after all priority one and two projects have been completed. Because the funds are generated from active coal mines, only priority one non-coal projects can be reclaimed.

The three reclamation priorities are:

1. Protection of public health, safety, general welfare, and property from extreme danger resulting from the adverse effects of past coal mining practices.
2. Protection of public health, safety, and general welfare from adverse effects of past coal mining practices, which do not constitute an extreme danger.
3. Restoration of eligible lands and waters and the environment previously degraded by adverse effects of past coal mining practices, including measures for the conservation and development for soil, water (excluding channelization), woodland, fish and wildlife, recreation resources, and agricultural productivity.

Using these general priorities, it was determined that there are 15 very large coal project areas and eight known non-coal projects that still need to be reclaimed.

To date, 88 AML projects have been completed at a cost of $23.77 million. The majority of the remaining coal related hazards are dangerous highwalls (19,750 feet/6,020 meters) and surface burning (10 acres/4 hectares). The majority of non-coal hazards are open portals (10) and vertical openings (19).

Photo by C. Justin Ireys

Figure 2. A highwall near the old Jonesville Mine.

AML Past Projects

The program has accomplished remediation and mine closures in nearly every region of Alaska. Dangerous highwalls have been re-sloped; coal refuse fires have been extinguished; hazardous materials such as PCBs, hydrocarbons, and asbestos have been removed; dangerous buildings and facilities have been demolished; and numerous mine openings have been sealed.

Highwall Projects

The AML Program has reclaimed nearly 12,000 feet (3,658 meters) of dangerous highwalls. These projects were all in the Sutton area near the old Jonesville Mine (*Figure 2*).

Dangerous Mine Openings

Since 1983 the program has closed 67 shafts and 45 portals. Depending on site conditions and location a variety of different closure methods can be used. Steel gate structures, polyurethane foam, backfilling, and concrete caps have all been used (*Figures 1 and 3*).

Coal Refuse Fires

Years of coal mining in the Sutton area left acres and acres of coal spoils that eventually caught fire from spontaneous combustion and camp fires. The AML program has spent $8.5 million to extinguish or suppress 67 acres (27 hectares) of coal refuse fires (*Figure 4*).

Photo by C. Justin Ireys

Figure 3. A gate closes an old mine opening.

Photo by C. Justin Ireys

Figure 4. Extinguishing coal refuse fires in Sutton.

Photo by C. Justin Ireys

Figure 5. Removing super sacks of PCB-contaminated soils near Suntrana Creek in the Healy Valley.

Hazardous Material

Hazardous materials leftover from abandoned mines can be dangerous to both people and the environment. Asbestos, PCBs, and hydrocarbons are often found at abandoned mine sites (*Figure 5*).

Hazardous Equipment and Facilities

Prior to improved and more stringent mining laws, mining companies simply walked away when ore reserves were depleted or uneconomical. These old mining buildings can be fascinating but they are also an attractive nuisance. As the buildings age, they become dilapidated and dangerously unstable. At the Suntrana Tipple site, the AML program spent nearly $1 million demolishing buildings and cleaning contaminated soil (*Figure 6*).

Photo by C. Justin Ireys

Figure 6. Old mine buildings become dilapidated and dangerously unstable like this one at the Suntrana Tipple site near Healy.

AML Future Projects: Healy Creek Strip Pits

From the 1920s through the 1960s large scale surface coal mining occurred in Healy Valley, Alaska, along the south side of Healy Creek. After the economical coal was mined out, the strip pits were abandoned without being reclaimed. This left behind well over 300 acres (121 hectares) of disturbed lands in seven individual pits, comprising a series of dangerous highwalls, steep footwalls, and out-of-pit spoil piles. The AML Program will be reclaiming this area for the next nine years.

Photo by C. Justin Ireys

Figure 7. The Hydraulic Pit is being reclaimed in 2014 and 2015.

Photo by C. Justin Ireys

Figure 8: The Vitro Pit will be reclaimed in 2016.

Photo by C. Justin Ireys

Figure 9. The East Cripple Creek Pit is scheduled for reclamation from 2017 to 2019.

Photo by C. Justin Ireys

Figure 10. The West Coal Creek Pit will be reclaimed in 2020.

Photo by C. Justin Ireys

Figure 11. The East Coal Creek Pit will be reclaimed in 2021.

Photo by C. Justin Ireys

Figure 12. The Center Pit will undergo reclamation in 2022.

Hydraulic Pit (Reclamation 2014-2015)

The Hydraulic Pit has dangerous highwalls and severe erosion issues from wind and water. The south and east walls are more than 300 feet (91 meters) high. A 600-foot (182-meter) -long portion of the north wall is nearly vertical and over 200 feet (61 meters) high. A significant amount of water flows through the pit, creating large amounts of erosion and re-deposition of sediments (*Figure 7*).

Vitro Pit (Projected Reclamation 2016)

Vitro Pit is approximately 2,500 feet (762 meters) long, bordered by a highwall 120-140 feet (36-42 meters) high along most of its northern length. There are also minor erosion issues from water discharge out of the northeast corner of the pit (*Figure 8*).

East Cripple Creek Pit (Projected Reclamation 2017-2019)

East Cripple Creek Pit is approximately 2/3 of a mile (1 kilometer) long and contains significant highwalls. Surface water flow is creating substantial erosion. A continuous, dangerous highwall borders the entire northern length of the pit, most of it at least 100 feet (30 meters) tall (*Figure 9*).

West Coal Creek Pit (Projected Reclamation 2020)

West Coal Creek Pit has roughly 1,500 lineal feet (457 meters) of continuous highwall that is 30-40 feet (9-12 meters) high and is surrounded by established vegetation (*Figure 10*).

East Coal Creek Pit (Projected Reclamation 2021)

East Coal Creek Pit is stable and dry, with little evidence of active erosion other than mass wasting. Highwalls and footwalls composed of poorly cemented sandstone and loose gravel are exposed in the upper 20 feet (6 meters) of the pit walls; however, vegetation surrounding the pit rim is thick and dense (*Figure 11*).

Center Pit (Projected Reclamation 2022)

The Center Pit has sides approximately 100 feet (30 meters) high and turquoise blue water of unknown depth and quality impounding the entire length of its floor. The west end of the pit is steeper than 1:1 (*Figure 12*).

Apex Pit (Projected Reclamation 2023)

The Apex Pit is the furthest east of the Healy Creek Strip Pits. On the far eastern end of the pit is a section of highwall measuring approximately 100 feet (30 meters) long and rising 40 vertical feet (12 meters) (*Figure 13*).

Photo by C. Justin Ireys

Figure 13. The Apex Pit will be reclaimed in 2023.

Alaska Park Science

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Photo by M. Johnson

A bird's-eye view of mountains in Noatak National Preserve, looking across the Red Dog mine.