Karst and Caves

Goal: Maintain and protect significant karst and cave ecosystems Forest-wide.

Objectives: Allow for the continuation of natural karst processes. Maintain the productivity of the karst landscape while providing for other land uses where appropriate.

Background: Karst is a comprehensive term that applies to the unique topography, surface/subsurface drainage systems, and landforms that develop by the action of water on soluble carbonate rock (primarily limestone and marble in Southeast Alaska). The dissolution of the rock results in the development of internal drainage, producing sinking streams (streams that sink into the stream bed or karst features), closed depressions, sinkholes, collapsed channels, micro relief karst features (e.g. karren), and caves.

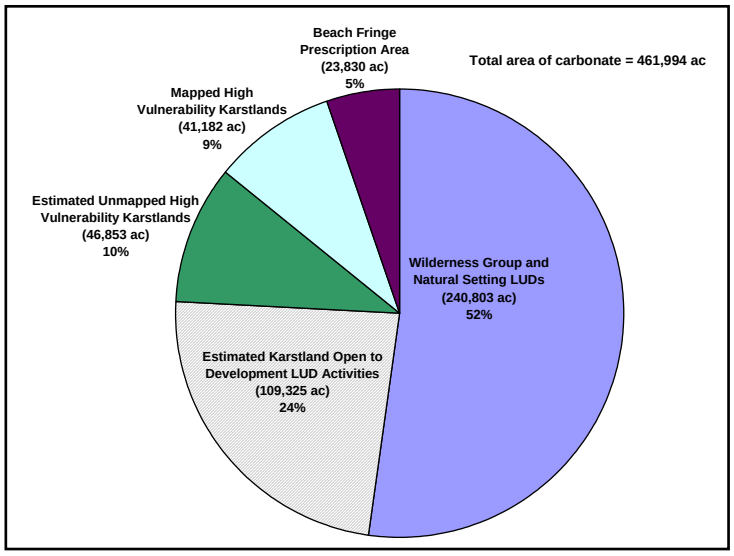
The geology and climate of Southeast Alaska are particularly favorable for karst development. Extensive areas of very pure carbonate (>95% $CaCO_3$), approximately 537,588 acres (840 square miles), are found within the boundaries of the Tongass National Forest. This includes carbonate bedrock on private, State, and Federal lands. Because of fractures in the carbonates, high annual precipitation, and peatlands adjacent to the carbonate bedrock, karst has developed, to varying extent, within all carbonate blocks. The Tongass National Forest contains the largest known concentration of solution caves in Alaska.

In Southeast Alaska the karst landscape can be characterized as an ecological unit found atop carbonate bedrock in which karst features and drainage systems have developed as a result of differential solution by surface and groundwaters. These acidic waters are a direct product of abundant precipitation and passage of these waters through the organic-rich forest soil and the adjacent peatlands. Recharge areas may be on carbonate or adjacent non-carbonate substrate. A few characteristics of this ecological unit include: mature, well developed spruce and hemlock forests along valley floors and lower slopes, increased productivity for plant and animal communities, extremely productive aquatic communities, well-developed subsurface drainage, and the underlying unique cave resources (Baichtal and Swanston, 1996, Wissmar *et al*., 1997, Bryant *et al*., 1998).

These karst areas are most comparable to those of karst lands found on Vancouver Island and the Queen Charlotte Islands of British Columbia, Canada, portions of Patagonia (Chile), Tasmania, and the west coast of the South Island of New Zealand. All of these areas have very steep surface slopes and subsurface hydraulic gradients, and very high levels of rainfall. These characteristics put them among the most dynamic karst terrains on earth, evolving and changing more rapidly and abruptly than karst in more moderate settings. The Karst Panel Report (Aley *et al, 1993*) found the karst lands of the Tongass to be of national and international significance for a variety of reasons. The Karst Review Panel in the summer of 2002 re-confirmed these findings (Griffiths *et al*., 2002). Both of these Panels consisted of world-renowned karst experts with a breadth of karst resource backgrounds and a wide variety of international exposure to karst areas and management considerations. Not only is the level of karst development and the karst hydrology and mineralogy globally significant, the paleontological and archaeological discoveries have, for the first time, written the prehistory of Southeastern Alaska and contributed to and challenged theories of the peopling of North America. This research in conjunction with associated and ongoing palynology and glacial history research is defining the paleoecology of the region.

The natives and local inhabitants of Southeast Alaska have long known of the presence of caves. The existence of well-developed cave systems was first formally reported in 1975 and mapping of the caves began in 1987. The existence of vast areas in which karst had developed was fully recognized in 1990. Though noted by early foresters and geologists, about this same time the interrelationship between timber production and highly productive forests atop the karst landscape became apparent. With the passing of the Federal Cave Resources Protection Act (FCRPA) in 1988, the Forest struggled with methods to protect the many caves throughout the landscape. At first, protection focused on only the large, significant karst features and cave entrances. Subsequent measures tended to look at entire karst hydrologic systems including contributing non-carbonate catchments. These measures were limited by the need to provide timber for the long-term timber sale contracts that supplied the pulp mills and wood-products industry in southeastern Alaska.

From 1993 to 1997, the Forest worked on revising the Tongass Land Management Plan (TLMP). One of the five "emphasis areas" identified in the TLMP revision was karst and cave resource management. Responding to the need for a management strategy, standards and guidelines were developed which provided for other land uses while taking into account the function and biological significance of the karst and cave resources within the landscape. This strategy had been developed during the last four years beginning with the recommendations of a karst and cave resource significance assessment completed by Aley *et al* in 1993 and combining the most current thinking on karst management issues. The Forest began adopting a land management strategy for the karst lands similar to "hazard area mapping" or "risk assessment". Referred to as "vulnerability mapping" or "karst vulnerability", this strategy assesses the susceptibility of the karst resources to any land use. Vulnerability mapping utilizes the fact that some parts of a karst landscape are more sensitive than others to planned land uses. The key elements of the strategy focus on the openness of the karst system and its ability to transport water, nutrients, soil and debris, and pollutants in to the underlying hydrologic systems. The strategy strives to maintain the capability of the karst landscape to regenerate a forest after harvest, to maintain the quality of the waters issuing from the karst hydrologic systems, and protect the many resource values within the underlying cave systems as per the requirements of the FCRPA.



Using the 1997 TLMP Land Use Designations (LUDs) and the most current geologic information, some 461,994 acres (722 square miles) of carbonate underlie the lands currently administered by the Tongass National Forest. Of those acres, 240,803 acres (52% of the Tongass karstlands) are in the Wilderness Group and Natural Setting LUDs. The remaining 221,190 acres (48% of the Tongass karstlands) of carbonate are in Development LUDs. Of these,

23,830 acres lie within the beach fringe prescription area. Of the karstlands in Development LUDs, 41,182 acres are mapped as high vulnerability. Of the remaining 156,178 acres of karst lands within the Development LUDs, it is estimated that through inventory and karst vulnerability assessments, that a minimum of 30% or 46,853 acres of additional high vulnerability karst lands would be characterized from those lands. Considering all these LUDs and projected inventory results, 352,668 acres or 76% of the karst lands are protected or are modeled to be. Therefore, the remaining 24% of the karst lands may be available for some level of management pending the results of a thorough inventory and karst vulnerability assessment. Some of these areas have already been harvested and management would be as pre-commercial and commercial thinning. Current GIS queries show a total of 95,479 acres (21% of the Tongass karstlands) of harvest on karst on lands managed by the Tongass National Forest.

The above areas of carbonate and LUDs on karst were generated in February of 2006 from the updated geology layer provided to the Tongass National Forest working in cooperation with the USGS in Anchorage. The USGS geology layer was queried to reflect rock units known to develop karst systems. The USGS geology layer was also modified to reflect recent mapping completed in conjunction with the Maden, Iyouktug, Sealevel, and Licking Creek Project Areas and mapping completed by the Forest on northwestern Etolin Islands.

The Forest Plan Standards and Guidelines for Karst Resources (1997 TLMP) outline a management strategy and define a process, which requires a karst landscape assessment be conducted. This four-step process first identifies and inventories the karst development and karst hydrologic systems, then evaluates karst resources as to their vulnerability or sensitivity to land uses affecting the karst systems. Consistent implementation of these guidelines across the Tongass has been a challenge. It is believed that this is partially due to unclear direction and limited experience of field personnel with this unseen resource. The flexibility in interpretation has resulted in conflicts between the Forest Service and concerned organizations, particularly the local caving community. Specifically the definitions of high, moderate, and low vulnerability karst have been interpreted differently in the field. Differences in interpretation are exacerbated by the lack of understanding of the way timber harvest impacts karst and cave resources, most notably by changes to hydrology and sediment delivery. The discussion in the 1997 TLMP does not make clear the difference between riparian management objectives and karst and cave management objectives. This understanding is critical for Forest Service employees tasked with implementing resource protection measures in the field. The 1997 TLMP did not discuss second growth management opportunities on karstlands and did not address the question of salvage of windthrown timber on karstlands.

In 2006 the Tongass National Forest initiated a process to amend the 1997 Tongass Land Management Plan (TLMP). Changes to the current published standards and guidelines have been proposed for the Forest Plan Amendment. Additional Geologic Special Interest Areas have been proposed in the Forest Plan Amendment, which recognizes areas of intense karst development across the Forest.

Multiple reviews of the current and proposed karst management strategies have been conducted by two panels, independent reviewers, and internally. These include Karst and Cave Resource Significance Assessment, Ketchikan Area, Tongass National Forest, Alaska

(Aley et al., 1993); Application of a Karst Management Strategy: Two Cases Studies from the Tongass National Forest, Southeastern Alaska The Challenges of Implementation (Baichtal, 1997); Heceta Sawfly Salvage Sale, Soils, Karst, and Cave Resource Evaluation, Heceta Island, Southeastern Alaska (Baichtal and Landwehr, 1997); Karst Vulnerability Assessment Review, Heceta Island (Aley, 1997); and Karst Management Standards and Implementation Review, Final Report of the Karst Review Panel (Griffiths et al., 2002). These reviews combined with implementation and effectiveness monitoring and resource specialist input form the basis for the proposed changes discussed below. The standards discussed here have been implemented since 1991 in one form or another. Thus, the Forest has some 15 years of implementation experience. The effectiveness and appropriateness of these standards have been discussed and debated internally and externally, both nationally and internationally. The final report from the Karst Panel in 2002 noted that "implementation of the 1997 TLMP Karst Standards and Guidelines has ensured a high level of protection for karst resources overall. The Panel noted high standards in both the philosophy of management, and the way that specific management practices were formulated and applied. Implementation of specific policies and procedures was found to be very good and in general compliance with the stated goals and objectives of the karst program."

Karst and Cave Question 1: Are Karst and Cave Standards and Guidelines being implemented?

Monitoring was completed on projects implemented under the direction of the Standards and Guidelines in the Forest Plan. Work completed under the Forest Plan Karst and Cave Standards and Guidelines included preliminary inventory, cave inventory and mapping, timber harvest unit and road reconnaissance, timber harvest unit layout, and road layout.

Monitoring Results

The Karst and Cave Standards and Guidelines outlined in Forest Plan were implemented to the fullest extent practicable.

Current ongoing projects and those with signed Records of Decision (RODs) focus on karst area protection. The Karst Resources Standards and Guidelines require that areas of high vulnerability karst within the project area be deleted from land considered for harvest. Karst lands included in project areas are typically low or moderately low vulnerability karst. The Karst Resources Standards and Guidelines are fully implemented in projects such as Gravina, Logjam, Tuxekan, Kosciusko, Scratchings, Kuiu Roaded, and Iyouktug Timber Sale Projects. Karst and cave resource evaluation was provided for the Thayer Creek Hydropower Project for the community of Angoon on Admiralty Island. Karst resource input was provided for a number of sales associated with the Small Sales Program on Thorne Bay Ranger District on Prince of Wales Island. Particular emphasis was placed on the inventory and design of the prescriptions and mitigation proposed for commercial thinning opportunities such as the Naukati and Winter Harbor Stand No. 587120524 of the Prince of Wales Wildlife Enhancement Commercial Thinning Proposal.

Efforts on the above projects included on the ground inventories by the Forest geologist and geology staff, soil scientists, hydrologists, fisheries, and timber specialists. Features were mapped and characterized and the streams flowing to and from them identified. Resource reports for each area were developed. The findings of these efforts have been mapped and

incorporated into the final reports. Also included were survey and inventory of some of the caves found within the project areas. Resource reports were provided to the planning interdisciplinary teams (IDTs) and incorporated into the final design of the projects and the project recommendations. These findings were also incorporated into the Chapter 3 discussions in the environmental documents associated with these projects.

Evaluation of Results

Recognition of the karst and cave resources across the Tongass is becoming more accepted. Resource specialists from various disciplines are bringing observations, concerns, and discoveries to the attention of the Forest Geologist for consideration during the inventory and design phase of projects. With the unification of the Tongass and consolidation of responsibilities there are still opportunities for increasing awareness of the karst and cave resources and the requirements for their management and consideration in project design. Implementation monitoring has shown the need for continued education and training of specialists across the Tongass. Specialists themselves have requested this training. Substantial changes have been suggested to the Karst and Cave Resource Guidelines for the 2006 Forest Plan Amendment effort that will hopefully better define the karst management strategy and vulnerability assessment process.

Action Plans

Continue implementation of the karst and cave resource standards and guidelines across the Tongass in all projects where resources may occur. Continue to increase awareness of potential karst and cave resources within proposed projects across the Forest. Continued training and involvement of karst specialists, hydrologists, soil scientists and other resource specialists is essential in implementation of the Karst Resources Standards and Guidelines. Funding levels have not allowed development of karst and cave resource management training modules for forest employees. Suggest using in the interim the training module developed by the British Columbia Ministry of Forests, “Managing Karst through Best Practices” on the web:http://www.for.gov.bc.ca/hfp/training/00008/index.htm.

Karst and Caves Question 2: Are karst and cave Standards and Guidelines effective in protecting the integrity of significant caves and the karst resource?

The Karst and Cave Standards and Guidelines outlined in Forest Plan and as modified by effectiveness monitoring ensure a high level of protection for significant caves and karst resources overall.

Monitoring Results

Effectiveness monitoring has been historically tied to post harvest monitoring and preliminary cave resource inventories. In 2006, little logging occurred on karstlands where mitigation had been prescribed. Monitoring of some of the small sales on the Thorne Bay Ranger District was conducted to evaluate the effectiveness of proposed mitigation. Monitoring of these sites found that prescriptions such as partial suspension and buffer windfirmness were achieved. Limited subsurface monitoring was accomplished. These included subsequent trips into known cave systems to document changes and pre-harvest inventory of karst features to

establish baseline inventories. No substantial changes as a result of management activities were documented within the known cave systems.

In 2006, the Geology SCEP student working on a Masters thesis completed a study within two un-harvested watersheds on Northern and Central Prince of Wales Island. The study began in May of 2006 with the collection of background information through surface reconnaissance, geologic mapping, and dye tracing of the watersheds through July. Once the catchments were been defined, the rain gauges, stem flow gauges, and Campbell data loggers were placed during the first week in August of 2006, and data was being collected weekly from August through November. The results of this study will provide a basis for further understanding the forest – karst dynamics in temperate rainforests. The storm events for this period and the storm hydrographs developed will be analyzed. The response of old growth karst watersheds to storm events will generate baseline data from which the effects of timber management can be modeled.

In 2006, a Masters Thesis study was completed and successfully defended, which looked at the influence of organic acid on limestone dissolution in the Beaver Falls Karst Area. The thesis examined the effects of organic acids on the water chemistry from a muskeg insurgence to a karst resurgence. The research covered the changing chemistry over the karst gradient as the muskeg waters change into buffered karst waters and looked at the dissolution rates as calculated by two different rate models and the field dissolution rates for both the muskeg and the karst resurgence waters.

In 2006, a study to verify the reliability of Lidar Depression Contours to accurately depict karst expressions on the landscape was undertaken by Tongass staff and two interns provided by the Geological Society of America. Two karst areas, one on Northern Prince of Wales Island and one on Kosciusko Island were analyzed. The results of this study will be summarized in 2007.

Monitoring of the effectiveness of the implementation of the Standards and Guidelines over the past few years has shown the need for clarification of the implementation procedures and identified changes to the standards needed. These changes were implemented in the Logjam, Staney, Iyouktug, and Kosciusko, Tuxekan, and Scratchings Projects. Changes to the current published standards and guidelines have been proposed for the ongoing Forest Plan Amendment. These changes capture the findings of past effectiveness monitoring and hopefully provide clarification of the implementation procedures.

Evaluation of Results

Programs such as the Small Sale Program on Thorne Bay Ranger District allow the karst management specialist to work closely with the presale forester, purchaser, and sale administrator to ensure consideration of karst resource values. As funding allows, the Forest needs to continue to strive for pre-harvest, immediately post harvest, and post harvest monitoring of areas where mitigation is applied. The results of the SCEP Students paired karst watershed study will be published in May of 2007. The results of the Lidar[1] Depression Contours analysis will be finalized in 2007.

[1] Lidar stands for Light Detection and Ranging, which is used as a survey tool to map ground features.

Action Plan

As timber harvest occurs in areas where karst is present and mitigation has been prescribed, effectiveness monitoring will occur as funding allows. As funding allows, tracer dye studies will continue to further characterize karst groundwater systems. Two similar watersheds on Northern and Central Prince of Wales Island were analyzed, both consisting of unharvested karst watersheds. Peak flow during storm events, base flow, stem flow and throughfall will be calculated and compared between the old growth catchments. Through analyzing these relationships in karst systems, this study will also complement ongoing research monitoring precipitation and throughfall in younger managed stands, older second growth, and old growth non-karst settings. Similar studies are planned for 2007.

Citations

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