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Subject: Karst Resource Forest Plan Adjustment Proposal Report. Rationale and Process used in making the Recommended Changes to the Plan

To: Lee Kramer, Forest Plan Adjustment Coordinator

This report outlines the proposed changes to the Karst Management Standards and Guidelines published in the 1997 Tongass Land Management Plan (TLMP). 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."

When the concept of vulnerability mapping was first proposed there were few examples of such assessments (Aley and Aley, 1993, Aley *et al*. 1993, and Eberhard, 1994). Since that time, karst vulnerability mapping has become widely used around the globe to assess the susceptibility of karst and cave resources and karst groundwaters to various threats and surface land uses (B. Andreo *et al.*, 2006; B.C. Ministry of Forests, 2003; Doerfliger et al., 1997, 1999; Eberhard, 1998; Kiernan, 2002, Krokonko *et al*., 2005, Renken *et al*., 2005, Zwahlen, 2003). These references are but a few of the examples of the many methods of assessing karst vulnerability in use today. For a discussion and comparison of some of the various karst assessment methods see pages 67 to 70 in A Preliminary Discussion of Karst Inventory Systems and Principles (KISP) for British Columbia (Stokes and Griffiths, 2000) and pages 293 to 297 in COST Action 620, Vulnerability and Risk Mapping for the Protection of Carbonate (Karst) Aquifers (Zwahlen, 2003).

The major focus and intent of the Tongass National Forest karst management strategy is to identify and protect karst systems and the caves and associated resources contained within, as per

the requirements of the Federal Cave Resources Protection Act of 1988 (FCRPA). The FCRPA is the primary U.S. law affecting caves. It requires protection of significant caves on Federal lands. A cave must possess one or more of the criteria outlined in 36 CFR Part 290.3 to be determined "significant". Though "non-significant" caves may exist on the Forest, most meet the criteria for "significant". The intent of this act is to protect cave resources not karst resources. However, it is important to recognize that caves and associated features and resources are an integral part of the karst landscape. Karst must be managed as an ecological unit to ensure protection of the associated cave resources. In practice, the Forest gives equal protection to important karst features, sinking or losing streams, springs, and caves.

The key factor of a particular karst system's vulnerability is that system's openness. The degree to which the surface is connected to the karst system conduits at depth relates directly to the effect of any planned land use. How open the system is gives insight to how quickly changes in hydrology, sediment and debris transport, and pollutants can affect the karst systems, the cave environments, and the surface resources they effect. In Southeastern Alaska, often the openness of the system is a function of that system's glacial history, the thickness and distribution of the glacial sediments, and that systems position on the landscape. A high density of solution and collapse features expressed at the surface indicates the presence of well-developed underground karst systems and surface connections. A low density of solution and collapse features indicate that either karst development is limited in some way or that it has been modified by glaciation and/or buried by glacial deposits. Under such areas however, karst systems and processes may be functioning at depth. Basing a management strategy on the systems openness makes that strategy applicable across many different occurrences, landscapes, and environments.

Issues:

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. Below is a list of the specific issues discussed in this report:

Karst Management Standards and Guidelines, Implementation Guide, and Training
Karst Vulnerability Assessments
Slopes in Excess of 72 Percent on Karst
Tracer Dye Studies

No-harvest Buffers for Specific Karst Features and Caves
No-harvest Buffers for Significant Caves
No-Harvest Buffers for Sinking or Losing Streams
Catchment Area Management
Carbonate or Autogenic Recharge Area Assessment Procedure (ARAAP)
Salvage of Windthrown Timber
Management of Second Growth Stands on Karst
Professionalism and Assessment Skills
Adaptive Management Approach

Background:

Karst is a comprehensive term that applies to the unique topography, surface and subsurface drainage systems, and landforms that develop by the action of water on soluble rock (primarily limestone and marble (carbonates) 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 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 Land Use Designations (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 LUD's 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.

Specific Issues Discussed:

Karst Management Standards and Guidelines, Implementation Guide, and Training

The 1997 TLMP Karst Standards and Guidelines were very limited in their scope referencing the karst management discussions in Appendix I stating, see Appendix I for "additional guidance". It is suggested that with this Forest Plan Adjustment there is an opportunity to bring the karst management guidelines up to date, incorporating needed changes discussed herein, and publishing them in the main portion of Chapter 4. For clarification of karst management program and strategy, it is suggested that an implementation guide be developed to explain the methodology and reasoning behind the guidelines. Additionally it is recommended that the Forest develop a karst resource and management training program so that staff and other resource specialist could better integrate the management of karst resources into their professional activities. Training would provide inexperienced staff with the required knowledge and confidence to actively participate in effective karst resource management.

The training program could focus on all the relevant aspects of the Forest's karst resource assessment and management. Training lessons would cover a range of topics, from the fundamentals of karst ecosystems to specific karst protocols. For example, lessons with a greater emphasis on karst vulnerability concepts could be made available to road engineers and personnel responsible for timber sale layout and administration.

Mechanisms for training could include formal short courses delivered by karst specialists already familiar with the karst resources of Southeastern Alaska and the principles of the Forest's karst management program. Group training would provide for more consistency in knowledge transfer. The training should be seen to be a valued career development activity by staff. Formal training, which could result in a certification process, would benefit both the Forest and the employees' professional development. At the introduction level the training could be web based as is provided by the British Columbia Ministry of Forests on the web:
http://www.for.gov.bc.ca/hfp/training/00008/index.htm

As awareness of the training program grows, the public will come to appreciate the value of more informed decision-making on karst resource management throughout the Forest (Griffiths *et al*., 2002).

Karst Vulnerability Assessments

The 1997 TLMP Karst Standards and Guidelines (Appendix I., 2), Inventory Karst Resources, states that "If it is determined that karst occurs in the project area, require a complete inventory." A literal translation of this standard requires that each and every karst feature be identified and located. In some instances this is appropriate, but not in all cases. If initial inventory indicates that the level of karst development and the density of karst features are so high that the landscape should be classified as high vulnerability, a complete inventory of all features is not necessary. It is important to document the level of karst development in the Karst Resource Report and the justification for the vulnerability classification. It is suggested that the requirement to inventory all features in every instance be removed from the karst standards and guidelines.

The 1997 TLMP Karst Standards and Guidelines (III, 4. (a-c) and Appendix I, 4. (A-c)) define low, moderate, and high vulnerability karstlands, their management objectives, and appropriate land uses. Our definition of these lands has evolved since these characterizations were first written. The proposed changes to the Forest Plan karst management standards and guidelines will incorporate the current understanding of these vulnerability classifications and reflect the changes discussed in the specific issues below.

Slopes in Excess of 72 Percent on Karst

The 1997 TLMP Karst Standards and Guidelines, Appendix I identified slopes grater than 72 percent gradient as high vulnerability. Implementation of the Steep Slope standard contained within the 1997 TLMP Soils Standards and Guidelines eliminates slopes greater than 72 percent slope from the tentatively suitable lands base. Subsequent TPIT clarification of the Steep Slope Standard insures that soil productivity and downstream resources are considered before approving timber harvest on slopes over 72 percent gradient. Implementation of the Steep Slope Standard discussed in the TPIT Clarification eliminates the need for a separate steep slope standard for karst lands. The Soils Standards and Guidelines and tentatively suitable criteria will address the steep slope issue. Therefore, it is suggested that the Steep Slope Standard in the 1997 TLMP Karst Standards and Guidelines be deleted.

Tracer Dye Studies

The 1997 TLMP Karst Standards and Guidelines (Appendix I., 3. (b)) require that in each project area a "sufficient number of dye traces (be performed) to assess the karst hydrologic system or systems within a study area." This has been interpreted to mean that in every instance tracer dye studies "need" to be performed. The importance of tracer dye studies to define the complexity of the karst systems hydrology cannot be overstated (Prussian and Baichtal, 2004). However it is not necessary to conduct these traces in every instance. In some areas, carbonates outcrop in narrow bands. Often, surface waters flow to these narrow carbonate outcrops sinking along their edge and resurfacing a relatively short distance down slope or across the outcrop. In these instances, the karst hydrologic system is not complex and it is felt that dye tracing is not necessary. Dye tracing may also not be necessary if a particular karst system and the associated sinking or losing stream or recharge area for that system receives a high category of protection.

It is proposed to change the guideline to require that "within each project area the need to conduct tracer dye studies will be determined by a karst management specialist or other resource specialist such as a hydrologist with karst specific experience or training. If tracer dye studies are determined to be necessary, the dye study needs to be carefully designed. Since subsurface flow paths are not predictable, an initial attempt to locate and sample all springs issuing from the karst area is necessary. Dye introduction sites should be selected to answer the particular resource concerns or threats. As an understanding of the systems complexity is established through initial successful traces, the sampling site strategy can be modified. Dye traces may need to be conducted at both low and high flows to determine the full extent of the karst groundwater system."

No-harvest Buffers for Specific Karst Features and Caves

The 1997 TLMP Karst Standards and Guidelines (Appendix I., 4.b.ii. (a)) call for a "minimum" of a 100-foot windfirm buffer to protect karst features. When developed in 1993, this requirement was modeled after TTRA stream buffers. Rational for this is that karst hydrologic systems are subsurface streams, and that sinkholes, caves entrances, collapse channels, etc. are surface expressions of underground streams. In application, this requirement became a maximum of a 100-foot buffer where windfirmness was seldom considered. Many of the buffers have failed (see Annual Monitoring and Evaluation Report for Fiscal Year 1999, Tongass National Forest, R10-MB-414, May 2000, pp37-43). The 1997 TLMP current standards (Appendix I., 4.b.ii. (c)) gives further direction to design the no–harvest buffers to be windfirm but does not give any specific direction.

It is proposed to change the guideline to require a no-harvest buffer of a "minimum of 100 feet of the edge of a cave, sinkhole, collapse channel, doline field, or other solution or collapse karst feature. Manage an appropriate distance beyond the no-harvest zone to provide for a reasonable assurance of windfirmness of that zone (pay special attention to the area within two site-potential tree heights of the no-harvest zone)." This guideline is modeled after the current riparian management strategy and the "reasonable assurance of windfirmness" buffers outlined. Though modeled after the current riparian management strategy outlined in the Forest Plan the objectives differ. The objectives of the riparian management strategy are to provide near-natural quantities of large woody debris for in-stream channel morphology, cover, nutrients, etc. The intent of the buffers surrounding karst features is to minimize the amount of both introduced coarse and fine woody debris and sediment entering a given karst system and to maintain, to the extent practical, the natural processes and environment surrounding those features. It is not intended that this level of protection would be applied for relative minor, isolated features. Appropriate protection measures for minor features should be designed on a case-by-case basis as field assessed by a karst management specialist.

No-harvest Buffers for Significant Caves

The 1997 TLMP Karst Standards and Guidelines, Appendix I provide for the establishment of windfirm no-harvest buffers above significant caves without specifying a minimum buffer width. It is suggested that the Tongass National Forest adopt a strategy similar to that prescribed in "The Karst Management Handbook for British Columbia" published by the British Columbia, Ministry of Forests in May of 2003. They prescribe reserves or management zones depending on

the cave's significance, depth below the surface, and passage size. The recommendation is based on the principle that the cave is primarily influenced by diffuse percolation from within a 45-degree angle on either side of the outside wall of the cave passage. The size and shape of the reserve can be projected to the surface using cave maps. Examples of their prescriptions can be found at the following on pages 24-25, and Figure 6:
http://www.for.gov.bc.ca/hfp/publications/00200/Karst-Mgmt-Handbook-print.pdf

It is proposed to change the guidelines to require that "No surface disturbing activity such as timber harvest, road construction, and/or quarry development will occur on lands that overlie a known "significant" cave. "Overlie" is defined here as the area between a lines projected from the outside walls of the cave passage at a 45-degree angle to the surface." In reality, lands that "overlie" a significant cave should be classed as high vulnerability even if other characteristics would suggest a lower rating.

As cave discoveries are made and those caves are mapped and inventoried, it is quite probable that very significant cave systems will be discovered. These might contain significant paleontological, cultural, or biologic resources or the system is of a particular size to warrant an extra level of protection. Cave systems such as El Capitan Cave on Prince of Wales Island, Arabica and associated caves on Heceta Island, Solstice Cave on Chichagof Island, and the Calamity Creek Caves on Revillagigedo Island are examples. It is suggested that on a case-by-case basis for such caves, a Geologic Special Area be defined and managed as such to protect these systems.

No-Harvest Buffers for Sinking or Losing Streams

Sinking streams are streams that disappear underground at a distinct sink point (i.e., swallet). Losing streams are streams that gradually lose water through an unconsolidated alluvial channel bed, or through a series of indistinct small openings, fractures, or sink points (BC Ministry of Forests, 2003). The 1997 TLMP Karst Standards and Guidelines (Appendix I., 4.b.ii. (a)) require a 100-foot minimum no-harvest buffer along losing streams, irrespective of length, if they are shown to contribute water through subsurface flow paths to Class I or II streams, significant caves or domestic water supplies, or if no groundwater tracing has been conducted. The current text would also appear to require the same level of riparian protection for minor tributaries and headwater reaches of sinking or losing streams. These measures effectively provide riparian protection within the entire watershed upstream of the particular swallow hole or loss points. The intent is to provide riparian protection only where it is reasonably needed. In some instances it is important to protect the entire length of a sinking or losing stream or its watershed depending on parameters such as gradient, channel type, soil characteristics, and susceptibility to mass wasting and erosion. It was not the intent of the guideline to apply karst management objectives to all streams or rivers above a sinking or losing point in all instances. Differences in interpretation of this guideline and its intent have led to confusion and implementation problems. Differences in interpretation are exacerbated by the lack of understanding of the way timber harvest impacts karst and cave resources, most notably fine debris 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. By way of example a Class IV surface water stream does not require a buffer under the 1997 TLMP Riparian Standards. To prevent degradation of a

significant cave, the same stream flowing into a sinkhole or cave would require a minimum 100-foot wind firm buffer under the guidelines.

Some sinking and losing streams can spend a large part of the year as dry stream channels, only flowing when the subsurface karst system backs up and overflows during major storms or runoff events. When these ephemeral streams flow, they can contribute major sources of sediment, organic material and other debris that are readily transported underground. On non-karst terrain, dry channels are generally not considered a major management concern; however, on karst, dry sinking or losing stream channels should be carefully considered for riparian management (BC Ministry of Forests, 2003).

The intent of Karst Management Objectives is to protect significant caves (a non-renewable resource) to the extent practical. The Riparian Management Objectives call for "maintaining riparian areas in mostly natural conditions for fish, other aquatic life, old-growth, and other riparian associated plant and wildlife species, water-related recreation, and to provide for ecosystem processes, including important aquatic and land interactions (Page 4-53 of the 1997 TLMP)." Water quality standards set numeric standards for turbidity, sediment, temperature, and other water quality parameters. The Alaska State Water Quality Standards generally allow some degradation of the water resource before a numeric standard is exceeded. The Karst and Cave Standards require a higher level of protection than offered by the riparian standards because 1) The FCRPA does not allow degradation of significant caves, and 2) Significant caves are a non-renewable resource.

It is proposed to change the guideline to require "protection of all sinking or losing streams and their tributaries irrespective of whether the channels carry perennial, ephemeral, or intermittent flows. A non-harvest buffer is required of a minimum of 100 feet from the edge of a sinking or losing stream within no less than ¼ mile (1320 feet) upstream of their swallow hole or loss point. Additional protection beyond this point many be needed and should take into consideration parameters such as gradient, channel type, soil characteristics, and susceptibility to mass wasting and erosion along the stream's or tributary's course or within the watershed. The karst management specialist should work in conjunction with hydrologists and soil scientists to design additional stream protection if needed. Manage an appropriate distance beyond the no-harvest zone to provide for a reasonable assurance of windfirmness of that zone (pay special attention to the area within two site-potential tree heights of the no-harvest zone."

The rational for the above guideline is that woody debris (large and small), sediment, and organic material can be transported downstream where it accumulates and clogs recipient karst features such as swallets or cave entrances and passages. This can restrict water from entering the subsurface and/or redirect flows to other subsurface openings or to the surface. Of particular concern is the introduction of fine sediment (e.g., silts, sands, clays) and fine organic material (e.g., needles, twigs, leaves) into subsurface cavities, including caves. These materials can coat underground surfaces, thereby impacting subsurface habitats and other cave resources or values (e.g., mineral formations or cave adapted organisms). The slow decay rate associated with underground environments in Southeast Alaska allows the organic component of this material to accumulate and persist over long periods of time (BC Ministry of Forests, 2003).

Catchment Area Management

The intent and interpretation of catchment area management has been confusing. The Karst Standards and Guidelines currently in 1997 TLMP, Appendix I states that "The vulnerability of the karst system's catchment areas should be considered equal to the highest down-gradient karst vulnerability values." In practice, designation of the entire catchment area may not be necessary. By the above definition the entire catchment area for any karst system regardless of size would always rank out as high vulnerability.

The 2002 Karst Panel Report suggested that the first objective of a catchment area management strategy for a karst system should be to establish, as closely as possible, the location and extent of surface areas contributing water either as allogenic or autogenic recharge to subsurface flow systems. Available water within non-carbonate or allogenic catchments occurs primarily as surface flow, while water on the carbonate or autogenic catchments rapidly infiltrates the ground. Both catchment types can contribute water to a subsurface flow system in karst (Griffiths *et al*., 2002).

Many karst watersheds receive part of their drainage from runoff originating on higher elevation non-carbonate rocks. This recharge originating from outside of the outcrop area of the carbonates is called "allogenic recharge" and it usually sinks or recharges the carbonate aquifer at specific points. This water quickly enters and is transmitted through the conduit part of the aquifer and is classed as concentrated "discrete" or "direct" recharge. Precipitation falling directly on the carbonate outcrop area is called "autogenic" recharge and may rapidly enter the subsurface through sinkholes at discrete points or may percolate down through a soil or cover layer and enter the aquifer or cave systems as diffuse recharge (Griffiths *et al*., 2002).

Catchment area management measures can be most effectively developed if both catchment types are delineated, and their sensitivity to cumulative land use activities is evaluated. Difficulties arise because relative proportions of the two catchment types can be diverse, and their sensitivities different; hence, different catchment assessment strategies need to be formulated for both types, each with its own set of guidelines. The guidelines developed should include a discussion of appropriate land-use practices and prescriptions. The strategy applied to old growth may be different than that applied to second growth (Griffiths *et al*., 2002).

<u>Non-carbonate (Allogenic) Catchments:</u> Where upstream surface runoff recharges a subsurface flow system in karst, the boundaries of the contributing non-carbonate catchment area can be defined using topographic divides. The surface allogenic flows can usually be followed to sink or loss points where they discretely recharge the karst system. It is suggested that traditional watershed analysis used for non-carbonate drainage basins are suited to this type of catchment. Monitoring of catchment stream flows and water quality can be used to judge the efficacy of a non-carbonate catchment area management strategy in relation to a karst system of interest (Griffiths *et al*., 2002).

<u>Carbonate (Autogenic) Recharge Areas:</u> The 2002 Karst Panel Report concluded that significant challenges remain in the area of catchment area management and watershed assessments for carbonate or autogenic recharge areas. Delineation of autogenic recharge areas is complicated because water may rapidly infiltrate the ground and cannot be traced over the surface. Karstic recharge areas may be shown to occur in more than one topographic basin, and unlike non-

carbonate catchments, they cannot be reliably inferred from local topography. Dye tracing techniques and more technically rigorous hydrogeologic investigations, as well as knowledge of insurgences and karst springs in the area, are often required (Griffiths *et al*., 2002).

Adaptation of "traditional watershed analysis procedures" for autogenic recharge areas is complicated by the hydrogeologic heterogeneity of subsurface karst. The sensitivity of different types of autogenic recharge to the removal of forest cover needs to be studied to support the development of an appropriate watershed assessment model. The basic science would suggest that removal of forest cover would initially reduce evapotranspiration and increase water yields in autogenic recharge areas, as is known to occur in non-carbonate catchments. However, the extent to which autogenic recharge mechanisms in karst are affected by this change has not yet been determined. The Panel considered it likely that future studies will show that certain autogenic recharge areas are more affected than others, depending on site characteristics such as soil depth and properties, epikarst development, and the type of karst features present. As an interim measure, the Panel suggests using the karst vulnerability assessment procedures to approximate the sensitivity of specific autogenic recharge areas. The cumulative effects of forest removal, and the residual effects of reforestation and second-growth management, should also be considered when developing strategies for autogenic recharge areas (Griffiths *et al*., 2002).

Monitoring spring discharge and water quality at connected karst springs may be the only practical way of monitoring the effectiveness of management in diffuse source areas. In view of the limitations described above, the Panel could not recommend a single catchment area management strategy to cover the range of catchment combinations. Each karst system will have a unique set of recharge characteristics, which, in turn, will determine the level of catchment area management required. The Panel believes that catchment area management strategies, regardless of recharge type, should focus on the karst system, as opposed to individual features. With particular reference to diffusely recharged karst systems with no identified discharge sites, the Panel believes the broader approach will ensure that a level of catchment area management is provided. Even where karst springs are identified, it may still be appropriate to consider autogenic recharge for the entire karst system rather than for an individual spring. The development of a conceptual model of autogenic recharge areas and inferred subsurface flow systems may be useful when assessing this type of catchment. The Panel further recommends that catchment area management strategies employ guidelines that can be adjusted and refined over time as more information is acquired, as opposed to rigid standards (Griffiths *et al*., 2002).

Carbonate or Autogenic Recharge Area Assessment Procedure (ARAAP)

An issue of concern not addressed within the present 1997 TLMP Karst Standards and Guidelines is a procedure for assessing autogenic recharge areas of karst systems and a threshold value for the amount of disturbance in any given system. The following discussion is taken from the 2002 Karst Panel Report (Griffiths *et al*., 2002). This discussion is offered to begin consideration of a procedure to include in the guidelines in the TLMP Adjustment. It is believed that the procedures discussed are logical and appropriate however, as mentioned, there are no examples to draw upon for setting the threshold value for disturbance within a given karst system.

The equivalent of the watershed analysis for non-carbonate catchments could be developed for

autogenic recharge areas (ARAs). This Autogenic Recharge Area Assessment Procedure (ARAAP) could be defined as: "an evaluation of the cumulative impact that proposed forestry activities in an ARA would have on the natural hydrological (and biological) characteristics and integrity of the associated karst system." The objective of this new assessment procedure would be to help ensure that incremental forestry activities in ARAs do not negatively affect an associated karst system.

The procedure would assess the impacts of forestry activities in ARAs on water quality and quantity at the karst system level. More specifically, the ARAAP would focus on the hydrological implications of forestry impacts on the natural functioning of soil and epikarst. The differentiation techniques of vulnerability mapping could be used for this purpose. Although primarily hydrology-driven, vulnerability mapping recognizes soil attributes and surface karst characteristics that correlate well with ecologic conditions for plants and animals.

Establishing the boundaries of an ARAAP unit could prove problematic. If limited to only those ARAs shown through groundwater tracing to drain to specific caves or karst springs, an ARAAP could eliminate other ARAs contributing water to other portions of the same karst system or unit. The preferred approach may therefore be to use the entire surface area above a contiguous karst unit as the ARAAP area. This may mean using modeling techniques to approximate the recharge characteristics of karst surface areas not shown to drain to specific caves or karst springs. The differentiation techniques of vulnerability mapping could be used in the modeling to recognize the variability of these karst surface areas.

In some cases, an ARAAP could be carried out solely for the sub-unit of the potentially larger host karst system. For example, if priority for analysis needs to be given to significant individual caves, or to karst springs with high downstream aquatic values, then only the delineated ARA sub-unit estimated to contribute water to the recipient karst environment would be considered.
Recommendations developed from an ARAAP would possibly include modification of the timing and layout of planned harvest units and roads, requirements for rehabilitation of roads, second-growth management, windthrow salvage, etc.

Rationale for ARAAP: Beginning in 1997 forestry activities have been restricted in ARAs to a level corresponding to their vulnerability class. The presumption is that the current set of TLMP standards and guidelines will continue to provide a high level of protection for karst resources in the future. However, ARAs commonly include historically impacted karst landscapes where hydrological recovery to pre-activity conditions is not nearly complete. Because the historic rate of forest cover removal was much higher on karst than for non-carbonate terrains, it can be expected that harvesting would have historically altered a high proportion of a particular karst system's ARA. Therefore, the potential for cumulative effects on the ARA would be relatively high unless hydrological recovery is evident based upon hydrological assessments and data indicating that the site index of the area has not declined subsequent to previous timber harvest.

Obviously, forestry activities in non-carbonate catchment areas could also have an effect on the associated karst system. Therefore a watershed analysis of the non-carbonate catchment area would still be required for karst systems with dual recharge processes (i.e., diffuse and discrete recharge).

Impact Indicators for ARAs: The following are suggested impact indicators for use in scoring or rating an ARAAP area for risk.

A. Forest Roads in ARAs

Impact indicator: Total length of all roads in miles divided by the total ARA area in square miles.

Forest roads can significantly alter the hydrology of ARAs, by covering up surface areas and interrupting autogenic recharge. Roads were often located on raised, rockier ground, where the level of epikarst development tends to be greatest. Initial road right-of-way clearing exposes soil to removal by rainwater and generally produces the same impacts as clear cutting. Grubbing can remove soil, and excavation, drilling and blasting for sub-grade construction can damage or destroy epikarst. The quantity of water that would normally infiltrate the ground beneath the road location is effectively reduced. Rainfall that is intercepted by the road surface can be transformed into concentrated surface water flows. These can be injected into the karst system at artificial roadside locations, significantly increasing recharge to that part of the system. Fines and other road materials, including automotive lubricants, can be delivered to the injection sites by the rapid surface runoff. Drainage ditches and other drainage structures have the potential to increase the infiltration capacity of roadside ARAs. Road rehabilitation and decommissioning can lead to further hydrological disturbances. If decommissioning of roads is undertaken with adequate forest regeneration and restoration of soil and epikarst processes, a hydrological recovery may be possible.

B. Road Quarries in ARAs

Impact indicator: Total number of road quarries divided by the total ARA area in square miles (with an adjustment factor for relative size of quarries).

Quarry development for forest roads removes soil cover, and damages or destroys the intersected epikarst. Abandoned road quarries are generally sites of more rapid recharge and lower epikarstic storage.

C. Timber Harvesting in ARAs

Impact indicator: Total number of clear-cut acres divided by the total ARA area in square miles (with a reduction factor to account for partial cutting, hydrologic recovery due to forest regeneration, second-growth management, and an adjustment factor to account for different vulnerability classes).

[Note: Studies are required to determine the approximate rate of hydrologic recovery for different vulnerability classes, and to identify if there are any non-hydrologic residual impacts on soil and epikarst, including biological impacts. The rate of recovery may be relatively rapid for low vulnerability ARAs, possibly approaching rates observed for similar non-carbonate areas. Full hydrologic recovery may not occur in high vulnerability areas without restoration measures (assuming that these measures would be effective).]

Timber harvesting operations in ARAs remove trees that play a critical role in the hydrology of soil and epikarst. Trees intercept rainfall and remove water through

evapotranspiration. Tree stands can also influence snow pack and snowmelt processes. Hydrologic recovery in an ARA can only begin to take place after the regenerating stand has re-established the interception and evapotranspiration characteristics of the original stand. Effects of tree removal are likely to be more pronounced in ARAs with thin soil cover. Yarding of trees can displace soil and infill epikarst cavities. Exposed, fine-textured or erodible soil can be displaced into epikarst cavities by rainwater during storm events. Soil strength can be reduced by the decay of tree roots after harvest. Displacement of soil and sediment can clog or reduce the capacity of epikarst pathways for air and water transfer, and possibly affect karst biota. Harvesting impacts are also likely to have been greater in ARAs with more numerous sinkholes and where there were no buffers around the sinkholes, etc. The highest impact sites are likely to be sinkholes with steep inner slopes, or sinkholes lined with fine-textured, erodible soils. The steeper the gradient and the greater the flow volumes, the greater the potential for material to move down and infill the bottom of sinkholes or to be washed into underlying conduits and/or caves.

D. Windthrow in ARAs

Impact indicator: Total number of windthrown acres divided by the total ARA area in square miles (with a reduction factor for salvage logging if defensible, and an adjustment factor to account for different vulnerability classes).

Windthrow in ARAs is another area where the basic information appears to be lacking. It is not known, for example, if salvage logging after windstorms improves the rates of hydrologic (and biological) recovery in high vulnerability karst, or if it can cause more damage than the original wind disturbance.

Further refinements to the ARAAP could be made to account for elevation ranges (for snow pack and snowmelt changes), road rehabilitation, second growth management, etc.

Setting Equivalent Clear-cut Area (ECA) Limits for ARAs

There are presently no credible Equivalent Clear-cut Area (ECA) limits in use that would recognize the unique hydrology and sensitivity of karst in ARAs. An ECA limit of 30% for ARAs could be used for our hypothetical purposes. Above 30% no further cutting would take place until the ARA conformed to the specified ECA limit, or until a more detailed ARAAP had been completed showing an adequate level of hydrologic recovery.

The following guidelines to setting ECA limits would also apply:

The ECA limit could be reduced if an ARAAP revealed significant hydrological disturbance above anticipated levels.

Where the harvestable area is less than 30% of the ARA, karst managers could use professional judgment to vary the ECA limit (but only if the hydrological disturbance could be kept to the same levels as for the normally specified ECA limit). [Note: This guideline would be applicable to ARAs with significant alpine or sub-alpine, or

similarly non-timber producing karst components.]

At any time, the detection of significant hydrological disturbance, substantial soil and epikarst disturbance, or significant deterioration in cave habitat, spring flow or quality could be cause to suspend harvesting in the ARA until the undesirable hydrologic (and possibly biologic) conditions were alleviated.

A more restrictive ECA limit could be used for ARA sub-units associated with significant caves or karst springs with exceptionally high values
.
The recommended ECA limit would be periodically reviewed and reformulated as the results of monitoring become available.

Size and adjacency of harvest units would still be considered in relation to other karst management objectives (e.g., connectivity for biodiversity, etc.).

ECA Coefficients

The following coefficients (for use in calculating ECAs) would be used to take into account the differing rates of hydrologic recovery for ARA sub-units of differentiated vulnerability classes:

Low vulnerability – 1
Moderate vulnerability – 1.5
High vulnerability – 2

Explanation: For example, hydrologic conditions in a high vulnerability karst sub-unit would take twice as long to recover.
The rate of hydrological recovery for a low vulnerability ARA sub-unit would be presumed to approach the rate for similar non-carbonate catchment terrain.

Salvage of Windthrown Timber

One issue not addressed within the present 1997 TLMP Karst Standards and Guidelines is the salvage of windthrown timber on karst. The practice that has evolved includes salvage of windthrown trees as long as no disturbance occurs directly adjacent to or within or over the karst feature or to not salvage within 100 feet of a karst feature. This has been designed on a case-by-case basis by the karst management specialist and as approved by the line officer. The rationale is that the windthrow event greatly disturbed the area surrounding the feature(s). If no further significant disturbance is created by harvest of the downed timber adjacent to the feature(s) the likelihood of additional sediment generation or runoff from the salvage action is minimal.

First, it is imperative that an understanding of the susceptibility of karst forests to windthrow be recognized and incorporated into harvest unit design. A comparatively high level of uprooting and rotational windthrow is typical for a karst site with a low or moderate level of epikarst development and moderately thick soil cover, whereas stem breakage is more typical of windthrow on sites with a high level of epikarst development and thin soils. Tree roots are not restricted to the soil layer on well-developed epikarst sites. Fractures and solutionally enlarged

joints in well-developed epikarst can provide enhanced root anchorage and resistance to uprooting or overturning. Also, in southern Southeast Alaska, much of the karst terrain is located on outer islands and is subject to stronger Gulf Stream winds than in protected areas. Many of these stands have regenerated from a catastrophic wind disturbance that occurred in the 1880's. Subsequent clear-cut harvest has resulted in substantial wind throw along harvest unit edges (Nowacki and Kramer, 1998). Post-harvest windthrow on karst landscapes can reduce the effectiveness of management prescriptions for the soil-epikarst system interface in low and moderate karst vulnerability areas, riparian areas and specific karst features, including caves. Windthrow can also compromise the integrity of high vulnerability karst areas. More specifically, windthrow on karst can potentially disrupt the soil-epikarst system interface and karst processes by dislodging bedrock and soil. Displaced soil can be readily transferred into vertical solution openings if the epikarst is particularly well developed. Soil loss can negatively impact site productivity, disrupt natural infiltration patterns and karst solution processes, obstruct subsurface pathways, and possibly affect the biology of surface and subsurface karst environments and/or downstream aquatic resources. The level of windthrow impact is closely related to the level of epikarst development and soil thickness on the site (Griffiths *et al.*, 2002). Our goal should be to design timber harvest to minimize the potential for windthrow so that salvage of the wind disturbed trees is not necessary.

It is proposed to add a section to the guidelines specifically discussing windthrow salvage on karst. It is suggested that "On lands underlain by carbonate, where salvage of windthrown timber is proposed, a karst resource inventory shall be conducted as described above. The openness of the underlying karst system, that systems vulnerability, and the likelihood of additional sediment production or surface runoff by harvesting the windthrown timber shall be determined. The appropriateness of salvage of windthrown timber on karstlands will be determined on a case-by-case basis in the field by a karst management specialist. Salvage is appropriate on low to moderate vulnerability karstlands when the karst management objectives can be met. Generally, no salvage shall be permitted on lands determined to be of high vulnerability, within 100 feet of a sinking or losing stream, a karst feature, or on lands that overlie a "significant cave". For relative minor, isolated features surrounded by low to moderate vulnerability karst, if the logging system to salvage the windthrown timber can be designed to not disturb the timber spanning or blown into the feature, salvage shall be permitted within 100 feet of the lip or edge of the feature. This salvage must be carefully designed. Before harvest, the sale administrator, purchaser representative and the karst management specialist should walk through the harvest unit to review the layout and resource management concerns."

Management of Second Growth Stands on Karst

A second issue not addressed within the 1997 TLMP Karst Standards and Guidelines is the management of second growth on karst areas. Due to the amount of past timber harvest on karst terrain on the Forest, the increased productivity of karst sites and the limited opportunities for obtaining timber supplies from old-growth landscapes, commercial management of second-growth stands on karst will begin in this decade. According to GIS queries, approximately some 95,475 acres (21% of the karst managed by the Forest) of harvest has occurred on karstlands managed by the Forest. Of those acres, 83,812 acres (39% of the karst in Development LUDs) have been harvested within Development LUDs. Pre-commercial thinning of many of these areas is ongoing. Approximately 13,996 acres were harvested before 1960 and are ready or will

be ready for commercial thinning in the near future.

Information regarding rainfall interception, throughfall and evapotranspiration indicates that stand composition can change the surface and subsurface hydrology. Unpublished data from Prince of Wales Island collected from 23 storm events in 2005 show that the clear-cut site (harvested in 1999) monitored received between 145 to 248 percent of the precipitation that was recorded as throughfall at the old growth sites. Conversely, the older second growth site (harvested in 1979) monitored received between 38 and 87 percent of the precipitation that was recorded as throughfall at the old growth sites (Prussian and Mayn, 2006). In the Karst Management Standards and Implementation Review, Final Report of the Karst Review Panel (2002) the panel summarized the lengthy discussions on second growth management. The panel felt that commercial thinning of over-stocked stands would hasten a return to more desirable stand conditions on historically harvested sites. The Panel believes this type of thinning could be safely conducted on low and moderate, and possibly selected high vulnerability karst sites. The preliminary data referenced above suggests that in young clear cut sites, precipitation amounts reaching the ground may increase from the natural old growth values by 1.45 to 2.5 times. This same data suggests that in older second growth sites that the throughfall may decrease by 1.1 to 2.7 times the natural old growth values. Less water in the karst groundwater systems could limit the areas they contribute water to and alter the biologic activity. Greater amounts of water into the karst groundwater systems could exceed the systems capacity forcing subsurface flow to the surface hence altering flow pathways and inviting sedimentation. Additional studies need to be conducted at multiple sites to substantiate these results. As well, these results did not consider stem flow. However, the preliminary data does support the concept that by commercial thinning of the older second growth stands on karst, returning the stand to closer-to-preharvest tree spacing, throughfall could be increased, hastening the hydrologic recovery of the site. The management of older second growth stands can also hasten the return to more natural stand characteristics and conditions.

It is proposed to add a section to the guidelines specifically discussing second growth management on karst. It is suggested that "On lands underlain by carbonate, where either pre-commercial or commercial thinning is proposed, a karst resource inventory shall be conducted as described above. The openness of the underlying karst system, that systems vulnerability to surface disturbance, and the likelihood of additional sediment production or runoff by thinning the second growth timber shall be determined. Pre-commercial thinning is appropriate on all karstlands when the karst management objectives can be met. Pre-commercial thinning to near the edge of karst features or the bank of sinking or losing streams is allowed, however, no slash or debris may fall or be placed in these features. It is probable that a zone equal to one tree height be left untreated to insure that no slash or debris will be placed in these features. If any introduces slash or debris finds its way into karst features or losing streams it must be removed by hand. Commercial thinning is appropriate on low to moderate vulnerability karstlands when the karst management objectives can be met. Generally, no thinning shall be permitted on lands determined to be of high vulnerability such as within 100 feet of a cave entrance, a karst feature accepting surface flow or of the edge of a sinking or losing stream within 1/4 mile upstream of their swallow hole or loss point. On a case-by-case basis, other karst features will be assessed as to their susceptibility to surface disturbing activities, the proposed harvest method, and the thinning prescription. The area surrounding these features is still considered high vulnerability

and should be mapped as such, however thinning of this sensitive area might be considered permissible. All features not fully protected would be buffered from their center to just outside the lip of the sink allowing for thinning within the area that would normally be a non-harvest buffer. It is probable that a zone equal to one tree height be left untreated to insure that no material will be placed in these features. All thinned timber will be directionally felled from the untreated area surrounding the karst feature and yarded away from the area. Any material landing on the slope break of the feature or within the feature will be hand removed. No yarding across or through the untreated area surrounding the feature will be allowed." Directional falling and yarding away from the karst depressions and features should provide adequate protection for water quality and karst features. It is believed that the benefit of hydrologic recovery of the areas adjacent to these features outweighs the risk of harvest. Again this should be assessed on a case-by-case basis.

Professionalism and Assessment Skills

The 1997 TLMP Karst Standards and Guidelines do not include a discussion of the professional skills and judgment needed in assessing karst resources. In the 2002 Karst Panel Report, the Panel noted that a strict adherence to high standards of professionalism must be demanded of all personnel engaged in karst resource evaluations (Griffiths *et al.*, 2002). Karst assessment requires professional skill and judgment, as well as experience with karst environments. It is essential to maintain staff with specific experience and/or training in karst assessments overseeing karst resource evaluations. General experience in karst processes is required at a minimum but Southeast Alaska-specific experience is necessary to fully characterize the karst systems found here. As mentioned above, the Forest needs to develop a training program for specialists who will conduct karst assessments. Specific discussion of training approaches can be found under the specific issue of "Karst Management Standards and Guidelines, Implementation Guide, and Training**."** The Forest should continue to foster relationships with local caving organizations and individual cavers under the current Memorandum of Understanding (MOU) to help with cave inventories and assessments.

Adaptive Management Approach

It is firmly believed that flexibility in the application of the 1997 TLMP Karst Standards and Guidelines as modified under the Forest Plan Adjustment is required, and that recommended procedures and practices should not be portrayed as "definitive." The proposed changes to the 1997 TLMP Karst Standards and Guidelines should allow karst managers to exercise their professional judgment in developing karst management strategies and prescriptions. As we have gained knowledge from implementation, monitoring, research, and studies, in many instances, recommended practices could have been modified and provided equal or better results for karst resource protection. Under current procedures, a Forest Plan Amendment is necessary to make a change to published standards and guidelines. It is suspected that karst management is not the only resource where changes to the standards and guidelines would be warranted. Possibly, it would be better to list our management strategies and procedures as "guidelines" based on the best science and our current understanding of the resource, subject to change with better understanding and research results?

Proposed Karst Management Guidelines

I. Strategy

A. Maintain, to the extent feasible, the natural karst processes and the productivity of the karst landscape while providing for other land uses where appropriate. This strategy is designed to assess a karst resource's vulnerability or sensitivity to a proposed land use and recognize the differences in degree of karst development and glacial history across the karst landscape.

B. The key elements of the karst strategy focus on the openness of karst and its ability to transport surface water, nutrients, soil and debris, and pollutants into underlying hydrologic systems. Strive to maintain the productivity of the soils of the karst landscape after harvest, to maintain the quality and quantity of the waters issuing from karst hydrologic systems, and to protect the many resources values within underlying significant cave systems as per the requirements of the Federal Cave Protection Act of 1988.

II. Management

A. Maintain a karst resource management program that will identify, evaluate, and provide appropriate protection and mitigation for karst resources. Evaluate karst resources as to their vulnerability to land uses affecting karst systems, as described in the Karst and Cave Resource Significance Assessment, Ketchikan Area, Tongass National Forest, Alaska (Aley et al., 1993), Karst landscapes and associated resources: a resource assessment (USDA Forest Service Gen. Tech. Rep. PNW-383) (Baichtal and Swanston, 1996), and the information provided herein.

B. Seek participation from interested individuals and organizations, such as caving groups, scientists, recreationists, and development interests in managing the karst resources.

C. Integrate and coordinate karst management with the management of other resources. Consider the function and biological significance of the entire karst landscape; recognize the importance of protection of karst systems, not solely specific karst features.

D. Public education and interpretative programs should be developed to ensure an increased understanding of the components and function of the karst landscape. Use research results to foster and promote conservation and further public education of karst resources.

E. Work with universities and other appropriate research facilities to foster partnerships to study and characterize the function and biological significance of karst landscapes. In order to maintain existing aesthetic and future scientific values, use non-consumptive research techniques as much as possible. See Karst Management Guidelines (VII) for specific information needs.

F. Manage the karstlands with an “adaptive management approach”. Guidelines should allow karst managers to exercise their professional judgment in developing karst management strategies and prescriptions. As knowledge is gained from implementation, monitoring, research, and studies, recommended practices should be modified to reflect the needed changes.

G. Karst assessment requires professional skill and judgment, as well as experience with karst environments. It is essential to maintain staff with specific experience and/or training in karst assessments overseeing karst resource evaluations. General experience in karst processes is required at a minimum but Southeast Alaska-specific experience is necessary to fully characterize the karst systems found here. The Forest should develop a karst resource and management training program so that staff and other resource

specialists could better integrate the management of karst resources into their professional activities. Training would provide inexperienced staff with the required knowledge and confidence to actively participate in effective karst resource management.

III. Karst Landscape Assessment

Karstlands impose land management challenges not encountered in non-karst areas because this three dimensional landform functions differently than other landforms. Karst resources must be evaluated according to their vulnerability to land uses affecting karst systems. Vulnerability mapping recognizes that some parts of the karst landscape are more sensitive than others to surface activities and groundwater contamination. These differences in vulnerability may be a function of the extent of karst development, the openness of the karst systems, and the sensitivity of other resources that benefit from karst groundwater systems. Assess karst resource vulnerability for both large geographic areas and site-specific projects. Complete vulnerability assessments of large geographic areas for any karst area where land-disturbing activities are planned. Conduct site-specific vulnerability mapping on a project-by-project basis or as field verification of the larger scale karst vulnerability assessment. Karst lands will be classified as low, moderate, or high vulnerability. This is a four-step process:

A. **Identify Potential Karst Lands.** Identify those lands underlain by carbonate rocks. As a practical matter, all lands underlain by carbonate rocks within the Forest should be considered a karst landscape. These include outcrops of limestone, marble, and dolomite. Karst has also developed within gypsum deposits on the Forest and caves or tubes can be found within some lava flows.

B. **Inventory Karst Resources.** At the beginning of any land-disturbing project planning effort, determine the project's proximity to or position on a karst landscape. If it is determined that karst occurs in the project area, require a complete inventory. Assess the degree and location of karst development. If karst is present, as a minimum the following information will be recorded:

   a. The degree to which karst has developed including the degree of epikarst development, the presence of caves, the presence of insurgences or sinking or losing water courses and resurgences or springs, sinkholes, collapse channels, and other karst features. If through initial inventory it is determined that the level of karst development and the density of karst features is so high that the landscape should be classified as high vulnerability, a complete inventory of all features is not necessary. It is important to document the level of karst development in the Karst Resource Report and the justification for the vulnerability classification. Document specific karst features on the “Karst Feature Form”. Document characteristics of the karst in the area of concern on the “Karst Classification Summary” form.

   b. When caves are identified that may be affected by the proposed land management activity, they will be surveyed and inventoried in accordance with cave management guidelines. To maintain continuity of inventory reports and cave maps, specifications will be addressed prior to commencement of inventory work. During inventory work caving ethics and protection of cave resources will be stressed.

   c. The relative position of karst features both within and adjacent to the planned

activity.

d. The slope of the land and the depth and nature of soil atop the karst.

e. The presence of any Class I or Class II streams being significantly contributed to from the karst hydrologic systems. It is only intended that streams that have had sufficient residence time or contact with the carbonate bedrock and which show appreciable geochemical change be considered. Temperatures less than 8.5 degrees C., pH ranging from 7.5 - 9.0, and specific conductance greater than 120 would be an indication of the highest value karst waters. It should be recognized that some normally dry drainage channels in a karst landscape will periodically carry large flows when the capacity of underlying conduits is exceeded during high flow events.

f. Sensitive habitats and features that might be adversely affected by land use changes in the area being investigated. These habitats and features must specifically include, among other things, streams important to fisheries and streams or springs used as domestic water supplies, habitats which support cave adapted organisms, and critical bat winter habitat and/or roosts. When considering karst streams and springs, the inventory work must recognize that many sensitive habitats and features are likely to be located appreciable distances away from points where waters enter the karst groundwater system. The sensitive habitats may also include unique or unusual plant communities associated with surface karst features or carbonate outcrops.

g. The results of the survey shall be documented and digitized onto the Forest's GIS database. The area's geology, location of karst features and caves, and the vulnerability of specific karst areas shall be recorded.

C. **Delineate Karst Hydrologic System and Catchment Area.** Define, to the extent feasible, the karst hydrologic system and the recharge area watershed or catchment area for each karst system. The character of the catchment area, i.e., the area, slope gradient, vegetation, water quality, soils, etc. controls the nature of the receiving karst system and defines the volume of runoff available for infiltration into the system. Recharge area delineation is a crucial component of vulnerability mapping; you must know where the water comes from and resurges to credibly assess and characterize possible impacts. At a minimum, the following information will be recorded:

a. During the inventory phase, record the location of all insurgences, sinking or losing streams, sinkholes or other features appropriate for injection of tracing dyes. Estimate water volume entering or discharging from the groundwater system at the time of the visit. Record the position and characteristics of as many resurgences or springs as practical believed to be associated with the particular karst system of interest. Describe prevailing weather conditions at the time of the visit and the precipitation trends over the previous 24 hours.

b. Within each project area the need to conduct tracer dye studies will be determined by a karst management specialist or other resource specialist such as a hydrologist with karst specific experience or training. If tracer dye studies are determined to be necessary, the dye study needs to be carefully designed. Since subsurface flow paths are not predictable, an initial attempt to locate and sample all springs issuing from the karst area is necessary. Dye introduction

sites should be selected to answer the particular resource concerns or threats. As an understanding of the systems complexity is established through initial successful traces, the sampling site strategy can be modified. Dye traces may need to be conducted at both low and high flows to determine the full extent of the karst groundwater system.

c. Record the results of the dye traces, indicating the relative position of the dye injection point and the position of the resurgence or spring where the dye was recovered. Record the tracer dye's travel time and concentration, if known. Record resurgences and streams that were sampled but no dye was recovered. Document and digitize results onto the Forest GIS database.

D. **Assess Vulnerability of Karst Terrain to Management Activity.** The final step is to delineate the land under investigation into various vulnerability categories. An area's vulnerability rating must be sensitive to potential surface management practices based on the extent to which epikarst has developed and the openness of the karst system. Where recharge is diffuse through deep soils the underlying karst is less vulnerable to increased sediment inputs and other pollutants than in areas where recharge is diffuse and soils are thin or nearly absent. Where soils are thin or nearly absent surface disturbances will almost always result in exposure of the epikarst, providing an easy pathway for sediment and other pollutants to enter the subsurface drainage network. Discrete recharge areas are especially vulnerable to ground disturbing activities because the flowing surface water can carry sediment and other pollutants directly to the subsurface drainage network. Karst vulnerability mapping recognizes the variability in karst terrain and uses the vulnerability concepts described here to assign a high, medium or low vulnerability rating to an area of karst terrain. The proposed ground disturbing activity is considered when determining mitigation or applying karst management guidelines. The vulnerability categories and their criteria are as follows:

a. Low Vulnerability Karstlands

i. **Classification Criteria.** Low vulnerability karst lands are those areas where resource damage threats associated with land management activities in the areas are not likely to be appreciably greater than those posed by similar activities on non-carbonate substrate. The following is a generalized characterization of these lands:

These are areas underlain by carbonate bedrock which are moderately-well to well drained, most commonly internally drained but surface streams may be present. Generally, these areas have been greatly modified by glaciation, and a deep (>40" deep) covering of glacial till or mineral soil, and little or no epikarst showing at the surface. The epikarst may be buried and/or ground off, depending on the intensity of glaciation. These lands pose little or no threat to organic, sediment, debris, or pollutant introduction into the karst hydrologic systems beneath through diffuse recharge. Often these are areas of little or no slope (<20%). These tend to be at lower elevations, i.e. <500 feet, however the elevation of low vulnerability karst will vary across the Forest.

ii. **Low Vulnerability Karst Management Objectives and Appropriate Land Uses** - These are areas where no special provision for the protection of karst values is considered necessary. Timber harvest and related activities

could be conducted in such areas in a similar manner to those normally employed on lands underlain by non-carbonate bedrock. Partial suspension yarding may be required. No quarry shall be developed atop karst without adequate site survey and design. Quarries should be properly closed after abandonment. Recreational development would be appropriate with consideration of karst resource values. It is possible that karst areas with high vulnerability will be found within and adjacent to areas found to be of low vulnerability. Along such boundaries or margins, guidelines for protecting these high vulnerability areas outlined under "Moderate Vulnerability Karst lands" (3.D. b. ii. (a)-(c)) shall apply.

b. **Moderate Vulnerability Karstlands**.

i. **Classification Criteria.** The moderate vulnerability karst lands are those areas where resource damage threats associated with land management activities in the areas are appreciably greater than those posed by similar activities on low vulnerability karst lands. The following is a generalized characterization of these lands:

These are areas underlain by carbonate bedrock that are well drained internally. Surface streams are rare. The soils of moderate vulnerability areas are a mosaic of shallow organic (20-40%, McGilvery Soils) and mineral (80-60%, Sarkar [<20" depth] and Ulloa [> 20" depth] Soils) with minor amounts of glacial till. The epikarst is moderate- to well-developed and is visible at the surface. These areas tend to be at higher elevations, i.e. >500 feet, and on knobs, ridges, and on the dip-slope of carbonate bedding planes when near the surface. The surface of these areas tends to be irregular and undulating, following the epikarst development which is the result of solution of the bedrock surface rather than solution and/or collapse features such as sinkholes. In other words, moderate vulnerability features are often the result of slow, diffuse processes rather than collapse or major subsidence processes, which typify high vulnerability features. Moderate vulnerability karst lands pose low risk to organics, sediment, and debris introduction into the karst hydrologic systems beneath. It is probable, but not always the case, that these areas contain or are adjacent to areas of high vulnerability.

Much difficulty lies in differentiating between the high end of the moderate vulnerability karst, and the low end of the high vulnerability karst. In using a classification system there is rarely an exact fit to the environment or specific area being investigated. As stated above, classification is dependent upon extent of karst development and openness of the system. This can be difficult when surrounded by an environment with no surface water streams, and limited exposure to the development of the underground system, as is often the case in these 'gray areas' between moderate and high vulnerability karst. Aside from the level of development and the openness of the system, the density of both karst features and exposed epikarst can be used when classifying the vulnerability of an area. A high density of features and/or very –well developed epikarst in a 'gray area' would result in a high vulnerability classification whereas a few minor features and moderate epikarst development with soil

retained might be classified as a moderate vulnerability area. It is crucial to evaluate the immediate area as well as the surrounding environment and any contributing characteristics when using this vulnerability system.

ii. **Moderate Vulnerability Karst Management Objectives and Appropriate Land Uses -** Management objectives on these lands is to provide for other land uses while taking into account function and biological significance of the karst and cave resources within the landscape. Timber harvest and related activities could be conducted in such areas under more restrictive guidelines than normally employed on lands underlain by non-carbonate bedrock. To protect the fragile soils found here, as a minimum, the yarding system selected may be required to achieve partial suspension. Longer timber harvest rotational periods may be appropriate. Reduced timber harvest unit size and a greater dispersal of harvest units may be required.

(a) Road Construction. Existing roads will be utilized in preference to the construction of new ones. Roads should avoid sinkholes and other collapse features and sinking or losing streams. Roads should not divert water to or from karst features. Measures shall be taken to reduce erosion and sediment transport from the road surface and cut slopes. Assess the need for ditches and culverts. Sediment traps, cut and fill slope revegetation, and road closure and revegetation may be appropriate. Because subsurface drainage networks may be more open to the surface in moderate vulnerability areas, additional design criteria may be required. Such criteria may relate to road construction methods, blasting, culvert placement and density, and sediment retention and erosion prevention. Road construction restrictions described below under "high-vulnerability prescriptions" may be required for these areas.

(b) Quarries. Existing quarries will be utilized in preference to the construction of new ones. No quarry shall be developed atop karst without adequate site survey and design. Quarries should be properly closed after abandonment. Recreational development would be appropriate with consideration of the karst resource values listed above, particularly with respect to reducing disturbance of sensitive soils and use of construction methods that avoid erosion and diversion of natural and road drainage waters into karst features.

(c) Karst Feature Buffers It is probable that individual features or areas with high vulnerability will be found within and adjacent to areas found to be of moderate vulnerability. Along such boundaries or margins the following guidelines shall apply:

1. No surface disturbing activity such as timber harvest, road construction, and/or quarry development shall occur within a minimum of 100 feet of the edge of a cave, sinkhole, collapse channel, doline field, or other collapse karst feature. Manage an appropriate distance beyond the no-harvest zone to provide for a reasonable assurance of windfirmness (RAW) of that zone (pay special attention to the area within two site-potential tree heights of the

no-harvest zone). The intent of the buffers surrounding karst features is to minimize the amount of woody debris and sediment entering a given karst system and to maintain, to the extent practical, the natural processes and environment surrounding those features. It is not intended that this level of protection would be applied for relatively minor, isolated features (i.e., where explicit of special management measures would not normally be required). Appropriate protection measures for minor features should be designed on a case-by-case basis as field assessed by a karst management specialist. When designing buffers to protect karst systems and their features, the buffer should be designed to be wind-firm. There is no credible standard buffer distance that will provide the assurance required to protect the systems from blow down of the forest within a given buffer. Each buffer must be carefully designed considering wind direction, blow down history, previous adjacent harvest, topography, and stand windfirmness. Delineated lands surrounding such features and systems must be of sufficient size to insure protection even if blow down occurs. It is suggested that the specific design of the buffers be an IDT recommendation working with the karst management specialist during the planning process for any given project. Not all features will require the RAW buffer considering the specific characteristics of each.

2. No surface disturbing activity such as timber harvest, road construction, and/or quarry development will occur on lands that overlie a known "significant" cave. "Overlie" is defined here as the area between lines projected from the outside walls of the cave passage at a 45-degree angle to the surface. In practice, lands that "overlie" a significant cave should be classed as high vulnerability even if other characteristics would suggest a lower rating. As suggested above, the specific design of the buffers should be an IDT recommendation working with the karst management specialist during the planning process for any given project.

3. As cave discoveries are made and those caves are mapped and inventoried, it is quite probable that very significant cave systems will be discovered. These might contain significant paleontological, cultural, or biologic resources or the system is of a particular size to warrant an extra level of protection. Cave systems such as El Capitan Cave on Prince of Wales Island, Arabica and associated caves on Heceta Island, Solstice Cave on Chichagof Island, and the Calamity Creek Caves on Revillagigedo, Island are examples. It is suggested that on a case-by-case basis for such caves, a Geologic Special Area be defined and managed as such to protect these systems.

4. Require protection of all sinking or losing streams and their tributaries irrespective of whether the channels carry perennial, ephemeral, or intermittent flows. A non-harvest buffer is required of a minimum of 100 feet from the edge of a sinking or losing stream within no less than ¼ mile (1320 feet) upstream of their swallow hole or loss point. Additional protection beyond this point many be needed and should take into consideration parameters such as gradient, channel type, soil characteristics,

and susceptibility to mass wasting and erosion along the stream's or tributary's course or within the watershed. The karst management specialist should work in conjunction with hydrologists and soil scientists to design additional stream protection if needed. Manage an appropriate distance beyond the no-harvest zone to provide for a reasonable assurance of windfirmness of that zone (pay special attention to the area within two site-potential tree height of the no-harvest zone. In the event that the stream is less than 1/4 mile long, the stream will be buffered to the stream's source.

5. The area surrounding resurgences should be protected to maintain the environment surrounding the springs and the quality of the waters flowing from them. Resurgences can however be classified as moderate or high vulnerability dependent upon their size, the habitat they provide, and the level of atmospheric connectivity between the resurgence and the underground karst system. Minor resurgences which seep out of the ground between gravels with almost no connectivity between the open atmosphere and the underground system will be classified moderate vulnerability. Appropriate protection measures for moderate vulnerability resurgences and springs should be designed on a case-by-case basis by a karst management specialist. All other resurgences will be classified as high vulnerability and protected as described in Karst Feature Buffers (III., D., b., ii., C., 1) above Special consideration should be given to the area immediately surrounding the springs to protect the flora and fauna often associated with the spring when considering the vulnerability.

c. **High Vulnerability Karstlands**

i. Classification Criteria. The high vulnerability karst lands are those areas where resource damage threats associated with land management activities are appreciably greater than those posed by similar activities on low or moderate vulnerability karst lands. These are the areas contributing to or overlying significant caves and areas containing a high density of karst features. The following is a generalized characterization of these lands:

These are areas underlain by carbonate bedrock that are well drained internally. Surface streams are rare. Karst systems and epikarst are extremely well developed and collapsed karst features may be numerous. These include all collapsed karst features, caves, sinking or losing streams, insurgences, open resurgences, and open grikelands (i.e., those without soil or moss infilling and with open connections to the subsurface). The highest vulnerability features are those that could produce and transport the greatest amount of sediment, debris, and/or organics if disturbed. These include till-lined sinkholes and cave entrances accepting a sinking stream, whether intermittent or not. Also considered high vulnerability are karstlands in which the epikarst is well- or extremely well-developed and the soils are predominately (>50%) very shallow organic (<10"deep, McGilvery), and (<50% mineral (<20" deep, Sarkar). The subsurface drainage network is highly vulnerable to sediment, organic matter, logging debris, and other pollutants generated as the result of surface activities.

ii. **Karst Management Objectives and Appropriate Land Uses.** These

areas shall be managed to insure conservation of karst values through the implementation of a high level of protection. Timber management and related activities should be excluded from these lands. Small expanses of these areas may be crossed by roads to access areas where harvest is appropriate, i.e. low or moderate vulnerability karst lands and non-carbonate areas. This would only be allowed if no other route or option was available and karst resource values would not be compromised. If roads must be built across areas of high vulnerability the following design and construction may be appropriate:

a. Minimize clearing limits and grubbing. Flush cut stumps to the ground. Do not deck logs pioneered from the road clearing limits outside the clearing limits.
b. Use a fill-type construction rather than a balanced cut and fill design. This most likely will be possible since the slope gradient of these areas are generally >15%.
c. Utilize log stringer bridges or similar structures to span across collapse features if necessary. Geotextile should be used to keep aggregate overlay from falling into the collapse feature.
d. Sediment traps and erosion control measures will be needed in most cases.
e. Same-season re-vegetation of the cut and fill slopes should be required to minimize sediment production potential.
f. A "plan-in-hand" review by the karst management specialist of the proposed road construction prior to actual construction is required.
g. The karst management specialist needs to work closely with engineering to carefully design these roads coordinating efforts with the planning team.

No quarry development would be allowed on these lands. Limited recreational development may be appropriate. Roads across such sensitive terrain except as described above, are inappropriate. Recreational facilities and trails would have to consider karst resource values and objectives discussed above, particularly with respect to reducing disturbance of significant epikarst features and sensitive soils and use of construction methods that avoid erosion and diversion of natural drainage waters into karst features. Karst lands found to be of high vulnerability shall be identified and removed from the commercial forest lands suitable land base.

IV. Catchment Area Management

The catchment areas for karst systems, comprised of carbonate or non-carbonate substrate, are an integral portion of those systems. Many karst watersheds receive part of their drainage from runoff originating on higher elevation non-carbonate rocks. This recharge originating from non-carbonate outcrops is called "allogenic recharge" and it usually sinks or recharges the carbonate aquifer at specific points. This water quickly enters and is transmitted through the conduit part of the aquifer and is classed as concentrated "discrete" or "direct" recharge. Precipitation falling directly on the carbonate outcrop area is called "autogenic" recharge and may rapidly enter the subsurface through sinkholes at discrete points or may percolate down through a soil or cover layer and enter the aquifer or cave systems as diffuse recharge. Catchment area management measures can be most effectively developed if both catchment types are delineated, and their sensitivity to

cumulative land use activities is evaluated. Difficulties arise because relative proportions of the two catchment types can be diverse, and their sensitivities different; hence, different catchment assessment strategies need to be formulated for both types, each with its own set of guidelines.

Non-carbonate (Allogenic) Catchments: Where upstream surface runoff recharges a subsurface flow system in karst, the boundaries of the contributing non-carbonate catchment area can be defined using topographic divides. The surface allogenic flows can usually be followed to sink or loss points where they discretely recharge the karst system. Traditional watershed analysis used for non-carbonate drainage basins are suited to this type of catchment.

Carbonate (Autogenic) Recharge Areas: Delineation of autogenic recharge areas are complicated because water rapidly infiltrates the ground and cannot be traced over the surface. Karstic recharge areas may be shown to occur in more than one topographic basin, and unlike non-carbonate catchments, they cannot be reliably inferred from local topography. Dye tracing techniques and more technically rigorous hydrogeologic investigations, as well as knowledge of insurgences and karst springs in the area are required. Adaptation of "traditional watershed analysis procedures" for autogenic recharge areas is complicated by the hydrogeologic heterogeneity of subsurface karst. The sensitivity of different types of autogenic recharge to the removal of forest cover needs to be studied to support the development of an appropriate watershed assessment model. The basic science would suggest that removal of forest cover would reduce evapotranspiration and increase water yields in autogenic recharge areas, as is known to occur in non-carbonate catchments. However, the extent to which autogenic recharge mechanisms in karst are affected by this change has not yet been determined. It is likely that future studies will show that certain autogenic recharge areas are more affected than others, depending on site characteristics such as soil depth and properties, epikarst development, and the type of karst features present. The Forest currently does not have a catchment area management strategy for autogenic recharge areas (ARAs). As an interim measure, use the karst vulnerability assessment procedures to approximate the sensitivity of specific autogenic recharge areas. The cumulative effects of forest removal, and the residual effects of reforestation and second-growth management, should also be considered when developing strategies for autogenic recharge areas. Each karst system will have a unique set of recharge characteristics, which, in turn, will determine the level of catchment area management required. It is recommended that catchment area management strategies employ guidelines that can be adjusted and refined over time as more information is acquired. The Forest should focus on research to define the parameters necessary to effectively manage these watersheds. It is suggested that some of the elements of this Autogenic Recharge Area Assessment Procedure (ARAAP) consider the following:

A. The Autogenic Recharge Area Assessment Procedure (ARAAP) could be defined as: "an evaluation of the cumulative impact that proposed forestry activities in an ARA would have on the natural hydrologic (and biologic) characteristics and integrity of the associated karst system." The objective of this new assessment procedure would be to help ensure that incremental forestry activities in ARAs do not negatively affect

an associated karst system.

B. Monitoring spring discharge and water quality at connected karst springs may be the only practical way of monitoring the effectiveness of management in diffuse source areas.

C. Define the boundaries of the ARAs to the extent practical through geologic mapping and/or tracer dye studies. In some cases, an ARAAP could be carried out solely for the sub-unit of the potentially larger host karst system. For example, if priority for analysis needs to be given to significant individual caves, or to karst springs with high downstream aquatic values, then only the delineated ARA sub-unit estimated to contribute water to the recipient karst environment would be considered.

D. **Impact Indicators for ARAs**: The following are suggested impact indicators for use in scoring or rating an ARAAP area for risk.

a. Forest Roads in ARAs. Total length of all roads in miles divided by the total ARA area in square miles

b. **Quarries in ARAs**. Total number of road quarries divided by the total ARA area in square miles (with an adjustment factor for relative size of quarries).

c. **Timber Harvesting in ARAs.** Total number of equivalent clear-cut acres divided by the total ARA area in square miles (with a reduction factor to account for partial cutting, hydrologic recovery due to forest regeneration, second-growth management, and an adjustment factor to account for different vulnerability classes).

d. **Windthrow in ARAs**. Total number of windthrown acres divided by the total ARA area in square miles (with a reduction factor for salvage logging if defensible, and an adjustment factor to account for different vulnerability classes).

E. **Setting Equivalent Clear-cut Area (ECA) Limits for ARAs**

There are presently no credible Equivalent Clear-cut Area (ECA) limits in use that would recognize the unique hydrology and sensitivity of karst in ARAs. An ECA limit of 30% for ARAs could be used for our hypothetical purposes. Above 30% no further cutting would take place until the ARA conformed to the specified ECA limit, or until a more detailed ARAAP had been completed showing an adequate level of hydrologic recovery.

The following guidelines to setting ECA limits would also apply:

a. The ECA limit could be reduced if an ARAAP revealed significant hydrologic disturbance above anticipated levels.

b. Where the harvestable area is less than 30% of the ARA, karst managers could use professional judgment to vary the ECA limit (but only if the hydrologic disturbance could be kept to the same levels as for the normally specified ECA limit). [Note: This guideline would be applicable to ARAs with significant alpine or sub-alpine, or similarly non-timber producing karst components.]

c. At any time, the detection of significant hydrologic disturbance, substantial soil and epikarst disturbance, or significant deterioration in cave habitat, spring flow or

quality could be cause to suspend harvesting in the ARA until the undesirable hydrologic (and possibly biologic) conditions were alleviated.

d. A more restrictive ECA limit could be used for ARA sub-units associated with significant caves or karst springs with exceptionally high values.

e. The recommended ECA limit would be periodically reviewed and reformulated as the results of monitoring become available.

f. Size and adjacency of harvest units would still be considered in relation to other karst management objectives (e.g., connectivity for biodiversity, etc.).

V. Second Growth Management on Karst

On lands underlain by carbonate, where either pre-commercial or commercial thinning is proposed, a karst resource inventory shall be conducted as described above. The openness of the underlying karst system, that systems vulnerability to surface disturbance, and the likelihood of additional sediment production or runoff by thinning the second growth timber shall be determined. Pre-commercial thinning is appropriate on all karstlands when the karst management objectives can be met. Pre-commercial thinning to near the edge of karst features or the bank of sinking or losing streams is allowed, however, no slash or debris may fall or be placed in these features. It is probable that a zone equal to one tree height be left untreated to insure that no slash or debris will be placed in these features. If any introduces slash or debris finds its way into karst features or losing streams it must be removed by hand. Commercial thinning is appropriate on low to moderate vulnerability karstlands when the karst management objectives can be met. Generally, no thinning shall be permitted on lands determined to be of high vulnerability such as within 100 feet of a cave entrance, a karst feature accepting surface flow or of the edge of a sinking or losing stream within 1/4 mile upstream of their swallow hole or loss point. On a case-by-case basis, other karst features will be assessed as to their susceptibility to surface disturbing activities, the proposed harvest method, and the thinning prescription. The area surrounding these features is still considered high vulnerability and should be mapped as such, however thinning of this sensitive area might be considered permissible. All features not fully protected would be buffered from their center to just outside the lip of the sink allowing for thinning within the area that would normally be a non-harvest buffer. It is probable that a zone equal to one tree height be left untreated to insure that no material will be placed in these features. All thinned timber will be directionally felled from the untreated area surrounding the karst feature and split yarded from the area. Any material landing on the slope break of the feature or within the feature will be hand removed. No yarding across or through the untreated area surrounding the feature will be allowed." Directional falling and split yarding away from the karst depressions and features should provide adequate protection for water quality and karst features. It is believed that the benefit of hydrologic recovery of the areas adjacent to these features outweighs the risk of harvest. Again this should be assessed on a case-by-case basis.

VI. Salvage of Windthrown Timber on Karst

On lands underlain by carbonate, where salvage of windthrown timber is proposed, a karst resource inventory shall be conducted as described above. The openness of the underlying karst system, that system's vulnerability to surface disturbance, and the likelihood of additional sediment production or surface runoff by harvesting the windthrown timber

shall be determined. The appropriateness of salvage of windthrown timber on karstlands will be determined on a case-by-case basis in the field by a karst management specialist. Salvage is appropriate on low to moderate vulnerability karstlands when the karst management objectives can be met. Generally, no salvage shall be permitted on lands determined to be of high vulnerability, within 100 feet of a losing stream, a karst feature, or on lands that overlie a "significant cave". For relative minor, isolated features surrounded by low to moderate vulnerability karst, if the logging system to salvage the windthrown timber can be designed to not disturb the timber spanning or blown into the feature, salvage shall be permitted within 100 feet of the lip or edge of the feature. This salvage must be carefully designed. Before harvest, the sale administrator, purchaser representative and the karst management specialist should walk through the harvest unit to review the layout and resource management concerns.

VII. Karst Studies and Monitoring

Maintain a monitoring strategy and program and promote karst studies that help define karst system characteristics and effectiveness of karst management prescriptions. This program should include but not be limited to the following:

1. Implementation and effectiveness monitoring to insure that karst management strategies and prescriptions are achieving the desired results in protecting the significant cave resources on the Forest and maintaining the function and biological significance of the karst systems.
2. Develop studies to better define our understanding of the complexity of the karst biologic and hydrologic systems. These should include but not be limited to:
   A. Tracer dye studies to further define the complexity of the karst groundwater systems and how diffuse and discrete recharge components move through the systems and how these systems respond to storm events.
   B. Studies that better define the impacts of timber harvest and road construction on the karst groundwater systems. These should include studies to determine the relationship between canopy interception, throughfall, and evapotranspiration in both harvested and un-harvested settings. These findings will better define aspects of the Autogenic Recharge Area Assessment Procedure (ARAAP) and help to determine credible Equivalent Clear-cut Area (ECA) limits.
   C. Increased biological inventories that address and define the ecological condition of karst environments in soil and epikarst, and in karst cavities other than enterable caves. Additional surveys of caves and springs to inventory cave-associated invertebrates. Between 1992 and 1995, collections from over three hundred cave and resurgence sites yielded at least five troglobitic and forty troglophilic invertebrate species. At least 3 of the five troglobitic species are new and as of yet undescribed.
   D. Continue to monitor discharge and water quality at various karst springs to determine processes affecting karst development, water quality and runoff volumes.

VIII. Mineral Development

The chemically pure carbonates of southeastern Alaska have long been considered for their

commodity values. Values are not determined solely on chemical purity but on brightness as well. The more pure the carbonate bedrock, the more conducive the bedrock is to karst development. It is not the intent of these standards and guidelines to restrict any lands from mineral development, though that may be appropriate if a specific project or area is allocated to the "Special Interest Area" Land Use Designation. The impacts of any proposed mineral development within the karst landscape can be analyzed through the environmental analysis that is triggered once a Plan of Operation is received.

Defining Key Terms

Due to the uniqueness of the karst landscapes, definition of several terms is needed for a better understanding of the resource. The following terms are used throughout the Karst management guidelines:

1. Karst" is a type of topography which develops as the result of the dissolution of soluble rocks, in most cases limestone and marble. Dissolution of the subsurface strata produces a landscape that is characterized by well-developed subsurface drainage, solution and/or collapse features such as sinkholes, dry valleys, vertical shafts, caves, and fluted rock surfaces (epikarst).

2. "Karst Landscape", in southeastern Alaska, can be characterized as a three-dimensional ecological unit found atop and within carbonate bedrock in which karst has developed and including the recharge areas on adjacent non-carbonate substrate. A few of the characteristics of this ecological unit include: mature, well-developed spruce and hemlock forests along the 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.

3. "Karst Resources" refer to all components of the karst system. These include both the physical and biological components of the karst landscape.

4. "Epikarst" is the surface of the karst. It is an intensely dissolved veneer consisting of an intricate network of intersecting dissolution-widened fissures, cavities, and tubes. It is this network of intersecting fissures which collect and transport surface waters and nutrients vertically to the underlying karst conduits

5. "Cave" is legally defined under federal law as: "... any naturally occurring void, cavity, recess, or system of interconnected passages beneath the surface of the earth or within a cliff or ledge and which is large enough to permit a[n] person to enter, whether the entrance is excavated or naturally formed. Such a term shall include any natural pit, sinkhole, or other opening which is an extension of a cave entrance or which is an integral part of the cave (36 CFR 261.2)". Speleologists use "cave" to refer to all parts, regardless of size, of an underground system that links openings and chambers and that may connect the system to the surface. The most common type of cave is formed in carbonates by dissolution. Included in the term "caves" are tree molds and lava tubes associated with lava flows, erosional caves, boulder caves, glacier caves, and littoral caves, as well as those formed by dissolution of bedrock.

6. "Significant Cave". Caves on National Forest System lands that possess one or more of the following features, characteristics, or values are considered potentially significant:

(1) Biota. The cave provides seasonal or yearlong habitat for organisms or animals, or contains species or subspecies of flora or fauna native to caves, or are sensitive to disturbance, or are found on State or Federal sensitive, threatened, or endangered species lists.

(2) Cultural. The cave contains historic properties or archeological resources (as defined in Parts

800.2 and 296.3 of this chapter respectively, or in 16 U.S.C. 470, et seq.), or other features included in or eligible for inclusion on the National Register of Historic Places because of their research importance for history or prehistory, historical associations, or other historical or traditional significance.
(3) Geologic/Mineralogic/Paleontologic. The cave possesses one or more of the following features:
(i) Geologic or mineralogic features that are fragile, represent formation processes that are of scientific interest, or that are otherwise useful for study.
(ii) Deposits of sediments or features useful for evaluating past events.
(iii) Paleontologic resources with potential to contribute useful educational or scientific information.
(4) Hydrologic. The cave is a part of a hydrologic system or contains water which is important to humans, biota, or development of cave resources.
(5) Recreational. The cave provides or could provide recreational opportunities or scenic values.

(6) Educational or scientific. The cave offers opportunities for educational or scientific use; or, the cave is virtually in a pristine state, lacking evidence of contemporary human disturbance or impact; or, the length, volume, total depth, pit depth, height, or similar measurements are notable.
(7) Specially designated areas. All caves located within special management areas, such as Special Geologic Areas, Research Natural Areas, or National Monuments, that are designated wholly or in part due to the cave resources found therein are determined to be significant.
7. "Cave Coordinator". An individual with responsibility for managing cave resources. The Forest Coordinator, has forest oversight responsibilities, while the District Cave Coordinator has on-the-ground responsibilities for cave resource management.
8. "Cave Entry Permit". A permit issued to allow entry into a closed cave. Usually the permit will allow entry of a maximum of six persons at one time.
9. "FCRPA". Federal Cave Resource Protection Act of 1988. This law establishes a Federal mandate to identify, protect, and manage caves on public lands administered by the departments of Agriculture and Interior. It may be referred to as the "Act".
10. "Cave Resources" includes any material or substance occurring in caves including, but not limited to, biological, cultural, mineralogical, paleontological, geological, hydrological, and recreational resources.
11.“Diffuse Recharge”. Refers to water entering the underlying karst through a multitude of small conduits that are not visible on the surface.
12. “Discrete Recharge”. Refers to water entering the underlying karst at a given point, such as a stream entering a cave or sinkhole.
13. “Solution features”. Karst features that result from the water erosion or dissolution of carbonate rock. Most epikarst is formed through direct dissolution of rock.
14. “Collapse features”. Features formed by the collapse of bedrock due to dissolution at depth. Sinkholes, dolines and collapsed channels are common forms of collapse features in Southeast Alaska.
15. “McGilvery Soil Series”. A typical pedon of McGilvery soil consists of less than 20 inches of well-drained organic matter over bedrock.
16. “Sarkar Soil Series”. A typical pedon of Sarkar soil consists of less than 20 inches of well-drained mineral soil over bedrock, specifically carbonate bedrock.

17. "Ulloa Soil Series". A typical pedon of Ulloa soil consists of more than 40 inches of well-drained mineral soils over bedrock, specifically carbonate bedrock.
18. "Sinkhole" or **"Doline"**(used interchangeably) are terms used to describe relatively shallow, bowl- or funnel-shaped depressions ranging in diameter from a few feet to more than 3,000 feet. These depressions are generally formed by dissolution of and subsequent settlement of bedrock to form a depression or collapse feature.
19. "Speleothem" means any natural mineral formation or deposit occurring in a cave or lava tube, including but not limited to any stalactite, stalagmite, helictite, cave coral, flowstone, soda straw, drapery, rimstone, or formation of clay, sand, or mud.
20. "Speleogen" refers to relief features on the walls, ceiling, and/or floor of any solution cave or lava tube. Speleogens are part of the surrounding bedrock. They include but are not limited to anastomoses, scallops, meander niches, petromorphs, and rock pendants in solution caves and similar features unique to volcanic caves.
21. "**Vulnerability Mapping"** or **"Karst Vulnerability"** is a management tool used to assess the susceptibility or sensitivity of the karst resources to any proposed land use. This type of approach is similar to "hazard area mapping" or "risk assessment". The thesis of this approach recognizes that not all karst development and associated resources are equal. Vulnerability mapping utilizes the fact that some parts of a karst landscape are more sensitive than others to planned land uses.
22. "Allogenic Recharge". Surface waters which flow to the karst groundwater system originating from outside of the outcrop area of the carbonates. These usually sink or recharge the carbonate aquifer at specific points. This water quickly enters and is transmitted through the conduit part of the aquifer and is classed as concentrated "discrete" or "direct" recharge.
23. "Autogenic Recharge". Precipitation falling directly on the carbonate outcrop area that enter the karst groundwater system through the epikarst, surface karst features, or by percolating down through a soil or cover layer into the carbonate aquifer as "diffuse" recharge.

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If you have any further questions, do not hesitate to contact me.

Sincerely,
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KARST FEATURE FORM

Project_____ Study Area:_____
Unit No._____Feature No._____ Field Team_____Date_____

Type of Feature
____Cave ____Insurgence ____Resurgence ____Sinkhole ____Collapse Channel
____Doline Field ___Other:_____

Location
Aerial Photo No. _____
Location Within/Adjacent to Unit _____
Distance/Direction from Nearest Road _____
GPS Position:
Easting:_____Northing(UTM)_____Elevation
:_____Error:_____

Dimensions
Opening Size_____ **Depth_____**
Shape_____ **Underground Human Access?_____**

Hydrology
Presence of Water (Describe)_____
Water Quality (for Insurgences and Resurgences):
Temperature (^{o}C)_____ pH_____ Conductivity _____
Flow Rate (gpm or cfs): Estimated_____ Measured_____

Cave Interior (Visible from Opening)
Formations?_____
Evidence of Bats?_____ Other Organisms?_____
Archeological Features?_____

Other Description (Not Included Above)_____
_____
_____
_____

Field Markings
Flagged?_____ Tagged?_____ Marker on Road?_____

Photographs
Type_____ Disk or Roll No._____ Photo No._____

KARST CLASSIFICATION SUMMARY

Project._____Study Area:_____Date:_____Assessors:_____
Unit No._____Road Segment No._____Aerial Photo No._____

Degree of Epikarst

_____ Little or no epikarst showing at the surface; epikarst buried or ground off by glaciation; epikarst development relatively shallow; no caves present; little or no threat of debris/pollutant introduction to subsurface karst.

_____ Moderate- to well-developed; epikarst visible at the surface; epikarst on knobs, ridges, or dip-slope of carbonate bedding planes near surface; surface irregular and undulating as a result of bedrock surface solution (not collapse features); little or no threat of debris/pollutant introduction to subsurface karst; displaced soils would be retained in adjacent epikarst channels; displaced soils would not be transported into epikarst and vertical solutional openings beyond rooting depth of young conifers.

_____ Extremely well-developed; collapsed karst features numerous; high vulnerability features present that could transport sediment/debris to subsurface karst; till-lined sinks/insurgences present; caves may be present.

Features Present (Karst Feature Form completed for those within unit):
____Caves ____Insurgences ____Resurgences ____Sinkholes ___Collapse Channels ____Doline Field
____ Other:_____

Additional Description: _____
_____
_____
_____
_____
_____

Drainage/Hydrology
___ Poorly drained, surface streams present, wetland indicator plants present
___ Moderately well- to well-drained internally; diffuse recharge; no surface streams present.
___ Well-drained internally; no surface streams present.

Karst hydrologic system contributes to Class I/II streams or domestic water supply?
___Yes ___No ___Possible ___Unknown
Describe Situation:_____
High value karst waters* present? ___ Yes ___ No ___ Possible ___ Unknown
Describe Situation: _____

Soils

_____ Area greatly modified by glaciation; deep glacial till or mineral soil; >40”(>3-1/2’) thick; soils moderately well- to well-drained; parent material is carbonate, till, or other bedrock.

_____ Mosaic of shallow organic soils (20-40% McGilvery) and mineral soils (60-80% Sarkar (<20”) and/or Ulloa (>20”)), with minor till.

_____ Predominately (>50%) very shallow organic soils (<10”, McGilvery); <50% mineral soils (<20”, Sarkar).

Slopes

___ Little or no slope; <20% (<11°) ___Slopes >20% (>11°) but <72% (<36°) ___Slopes >72% (>36°)

Elevation
___ Lower Elevation, <500’
___ Higher Elevation, >500’; knobs, ridges, or dip-slope of carbonate bedding planes near surface
Elevation range for area _____

Sensitive Habitats
Note any evidence of the following:
_____Fish in streams ____Streams draining to Class I/II streams ____Streams/springs used as domestic water supply
_____Bat habitat/roosts _____ Other cave organisms _____Archeological/Paleontology in caves _____Unique plant habitat
*Streams that have been in contact with carbonates and show appreciable geochemical change. Typical parameters for high value waters: temp. > 8°C, pH 7.5-9.0, specific conductance >120. See Karst Feature Form for site-specific data.