PHYSICAL PLANNING GUIDE

The following are the four objectives of the Master Plan for the Mauna Kea Science Reserve:

1. **Prepare a Master Plan consisting of a physical planning guide, maps, geographic information system, and criteria, which manage the use of the resources of the Mauna Kea Science Reserve.**

   - **Protect natural resources (e.g. Wēkiu bug habitat, alpine ecosystems);**
   - **Protect historic and Hawaiian cultural resources and practices (e.g. archaeological sites, cultural landforms);**
   - **Protect and enhance education and research (e.g. astronomy, ecology, geology);**
   - **Protect and enhance recreational opportunities (e.g. skiing, hiking).**

   The physical planning guide will enable the sustainable use and enhancement of these four resource components. The natural resource component documents the extent of significant habitat areas and unique geology areas, and delineates preservation areas. The historic and Hawaiian cultural component identifies archaeological sites and culturally significant landforms to be preserved. Appropriate sites for the future locations of astronomy facilities are identified, with respect for natural and cultural resource preserve areas. Lastly, the recreational uses of the mountain are defined.

2. **Analyze and depict the physical implications of uses and address and propose mitigation of environmental impacts.** The Master Plan considers the physical presence of astronomy facilities, and other buildings and infrastructure on the mountain. A Geographic Information System (GIS) is utilized to provide a resource-based siting analysis of environmental conditions.

3. **Guide the planning of physical development in the summit area, not only in terms of the location of facilities, but in regard to character, size, mass, color, and other physical attributes.** The plan locates proposed new facilities and includes design criteria, which are intended to mitigate potential visual and environmental impacts. These include topographic shielding, setbacks, scale and colors. A three-dimensional simulation program is used to evaluate the potential visual impacts and effectiveness of mitigation proposals that guide the siting and design of new facilities.

4. **Define the infrastructure and support facility elements required for natural and cultural programs, education and research programs, and recreation uses.** The plan addresses the infrastructure support elements for facilities in the Science Reserve, including the roadways, electrical power supply and communications network.

METHODOLOGY FOR THE PHYSICAL PLANNING GUIDE

The updated Physical Planning Guide for the Mauna Kea Science Reserve consists of four components, including: (1) Natural Resources, (2) Cultural Resources, (3) Education and Research, and (4) Recreational Resources. Resource elements were overlaid upon each other to create a base for the master plan, identifying opportunities for both preservation and uses.

This resource overlay process employs a Geographic Information System (GIS) format. A Geographic Information System is a computer-based tool for mapping and analyzing resource data that integrates spatial and non-spatial information to provide tailored analytical and mapping capabilities. Resource data are compiled in the GIS to show the extent of resources and uses. New information is obtained directly from government and consultant surveys, field research, and literature studies conducted since the 1983 master plan. Additional information is derived from the meetings of the Mauna Kea Advisory Committee, the findings of consultant studies, individual interviews, and meetings with authorities with expertise in relevant disciplines.

Criteria are developed for each of the resource maps to delineate boundaries for areas to be proposed for preservation and areas for potential use. The key factors considered in recommending areas either for preservation or compatible use are the presence or absence of important natural, cultural, education and recreational resources. The methodology used in creating individual plan components is described below.

Natural Resources Components. This component of the master plan delineates the presence of unique geology, flora and fauna resources within the Science Reserve. Significant natural resource areas are identified in the plan. GIS mapping is used to produce composite studies of each resource layer, including a graphic overlay of natural resources. Refer to Section IV for detailed information on the natural resource components of the Science Reserve.

Cultural Resources Components. GIS mapping is used to present each cultural resource component, including archaeological sites, places of cultural importance, and culturally significant landforms in the Science Reserve. Refer to Section V for detailed information on the cultural resource setting.

Educational and Research Components. Sites for new education and research facilities are determined utilizing the natural and cultural resources GIS layer components. The boundaries of a proposed development area are defined by balancing the sites needed by proposed astronomy facilities and specific natural and cultural resource elements, being limited to those areas where impacts to important natural and cultural resources can be avoided or minimized. The Hale Pōhaku mid-elevation facilities are also studied for

potential future improvements to facilities and infrastructure. Refer to Section VI for detailed information on the education and research components of the Science Reserve.

Recreational Resources Components. The component for the recreational resources in the Science Reserve addresses areas for skiing, snow play, and hiking. This component addresses the suitability of areas for continued or expanded recreational use, with recommendations for area limits and support facilities. Refer to Section VII for detailed information on the recreational resource components of the Science Reserve.

NATURAL AND CULTURAL RESOURCES COMPONENTS

The first integration in the Physical Planning Guide is the relationship of natural resources and cultural resources. From a Hawaiian perspective, there is not a differentiation between the natural and cultural resources of the land, rather they are a unity. In this plan, the natural and cultural resource elements are addressed in an integrated approach to carry equal importance in the Master Plan.

Overall objectives for natural and cultural resources:

1. Promote a greater knowledge base and understanding through the planning process, focussed on:
   - Critical natural resources, to include flora, fauna, and natural landforms, and
   - Archaeological and cultural resources, Hawaiian cultural practices, modern practices and significance of sites, names, and geophysical elements.

2. Protect and preserve, through planning and management:
   - Unique geological features and biological communities, recognizing the symbiotic relationship between the two in the Science Reserve which form unique ecosystems, and
   - Cultural resources in a sustainable manner so future generations may share in the understanding and knowledge of the mountain's archaeological sites and culturally significant landforms and places.

3. Enhance opportunities and protect:
   - Natural resource areas for recreation in a manner that both sustains the resources and promotes the safety of individuals, and
   - Opportunities for individuals and groups to engage in cultural practices.

4. Allow for current and future use of natural resources for educational programs and cultural practices for the community, schools and universities, and visitors.

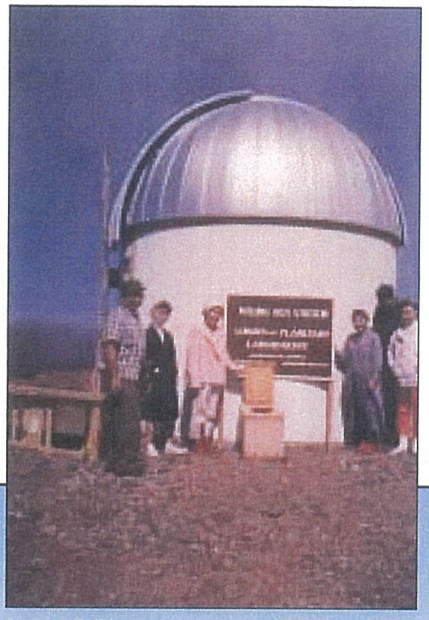
5. Protect the mountain's natural landscape to preserve its scenic values, and preserve the cultural landscape to enhance meaning, relationships, and resources for modern appreciation, research, and practice.

6. Define specific areas and criteria for natural resource use and cultural resources and practices, as applicable, to allow for sustainable, integrated planning and management.

Natural and Cultural Resources Map. The objectives and goals for the natural and cultural resources map arise from the issues surrounding the past and present uses of the mountain. In the recent past, the mountain's natural and cultural resource issues have each been handled in an isolated manner, whether it has involved the Wēkiu bug population, archaeological sites, or the use of the *pu'u* to locate astronomy facilities. We now have better knowledge of these resources and understand that they are inter-related and need to be planned in an integrated fashion, not individually. For example, the natural direction for past astronomy development has been to utilize the highest elevation locations found at the tops of the *pu'u*. Years ago, Pu'u Poli'ahu was tested for its qualities as an astronomy site, and from a technical basis, it is considered to be a prime potential site (See Figure IX-1). However, our increased understanding of the Hawaiian cultural importance of the mountain's *pu'u*, as well as their unique ecological components, now guide future planning toward preserving these important features.

From a natural resource perspective, the primary issues concern the Wēkiu bug and scenic views. The major *pu'u* in the upper slopes of Mauna Kea provide the only known habitat area for the Wēkiu bug. Some *pu'u* have been found to contain the Wēkiu bug, while others have similar habitat qualities and have the potential for supporting populations of this endemic arthropod, thereby motivating plans to preserve all *pu'u.* Scenic views of the summit are experienced within the Science Reserve and from off-mountain locations. All major cinder cones which are undeveloped will be protected from future development by astronomy or other interests. These include the following *pu'u*: Ala, Hau Kea, Hoaka, Kūkahau'ula, Lilinoe, Mahoe, Makanaka, Poepoe, Pohaku, Poli'ahu, Ula, and Wai'au. Prohibition of development of modern man-made features on all the currently undeveloped *pu'u* will protect the scenic natural views to and from these landforms (See Figure IX-2). Preservation of each *pu'u* will also retain the integrity of a cultural landscape spanning from Kūkahau'ula (the summit) through Poli'ahu, including Lake Wai'au and the adze quarry at Keanakāko'i in the adjoining Natural Area Reserve. A principal recommendation of this plan is the preservation of the natural and cultural landscape of the Science Reserve by protecting all of the major undeveloped *pu'u* and the intervening areas from disturbance.

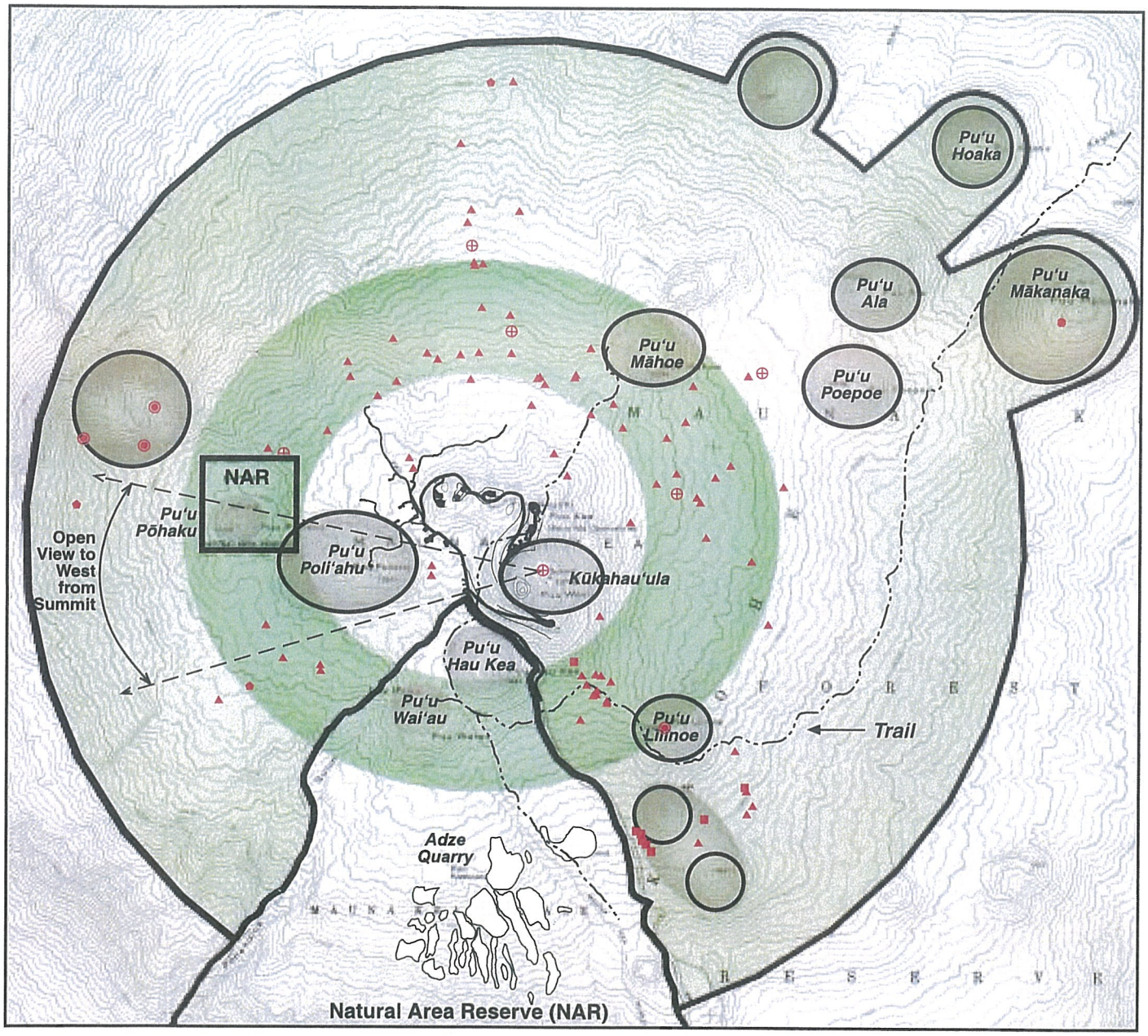
The Master Plan also envisions the preservation of the natural cultural landscape in the Science Reserve (See Figure IX-3). Archaeological sites are found with the greatest frequency in a band below the summit area, mostly evident at about the 13,000 ft. level.



Lunar & Planetary Laboratory Test Station
(formerly on Pu'u Poli'ahu)

Pu'u Poli'ahu

Pu'u Poli'ahu and Lunar and Planetary Laboratory Test Station



Archaeology

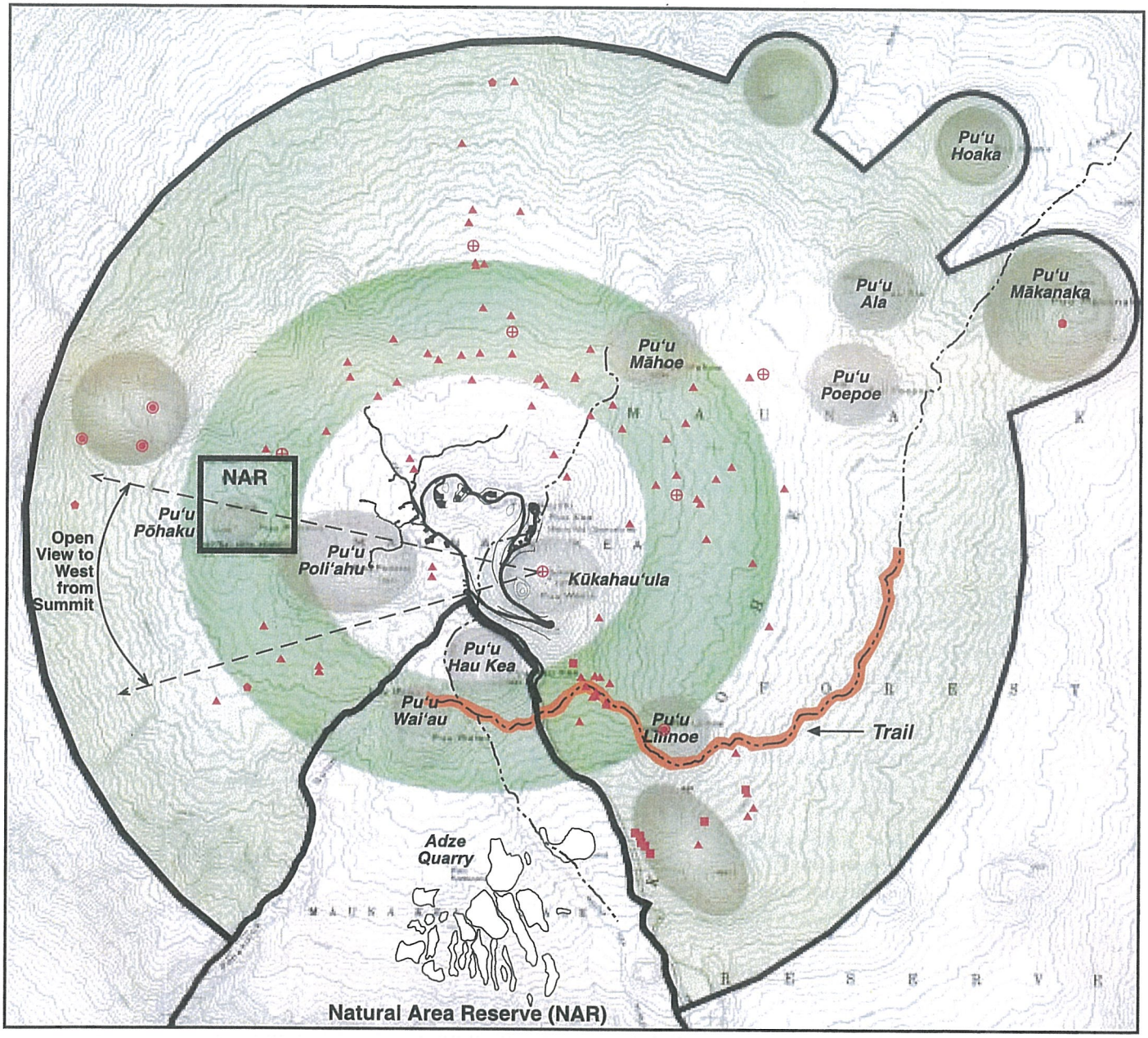
- Shrines
- Marker
- Unknown
- Workshop

- 25' Contour Intervals
- Band of Archaelogical Sites at 13,000 ft. elev.
- Historic Trail Linking Cultural Resources
- Undeveloped Pu'u

0' 2000' 4000' 8000'

NORTH

Undeveloped Pu'u



Archaeology

- Shrines
- Marker
- Unknown
- Workshop

- 25' Contour Intervals
- Band of Archaelogical Sites at 13,000 ft. elev.
- Historic Trail Linking Cultural Resources
- Undeveloped Pu'u

0' 2000' 4000' 8000'

NORTH

Cultural Landscape Map

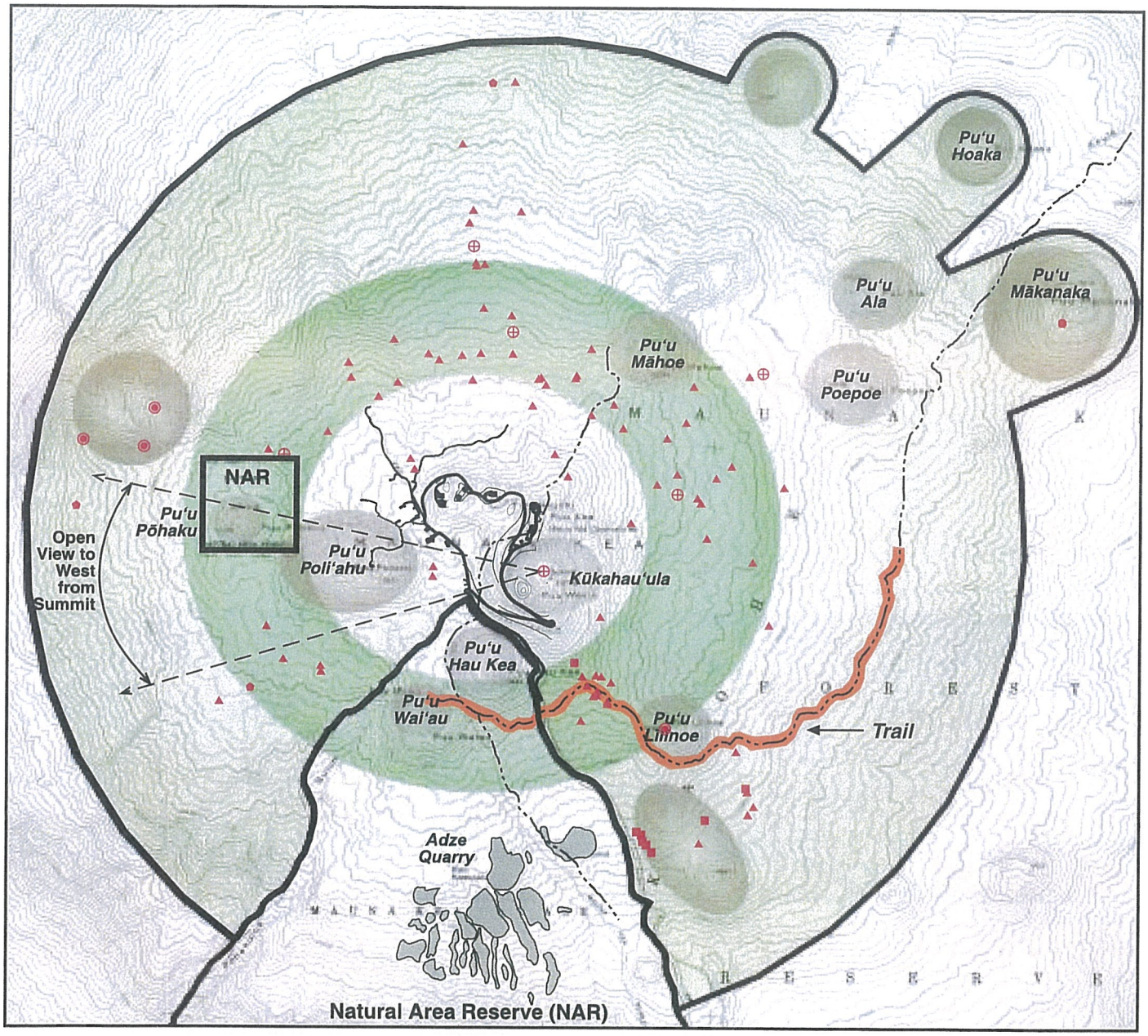
According to cultural sources, Lake Wai'au (in the NAR) and its surroundings, including the *pu'u* within the Science Reserve, are all culturally significant places. The Plan views the archaeological sites of the summit region as a whole rather than in an isolated context. According to McCoy (February 1999), the abundance of shrine complexes and the accounts of cultural importance of the *pu'u* in the upper slopes, indicates that the area was a ritual center. Therefore, the physical plan links the significant landforms with the archaeological sites clusters, Wai'au and the adze quarry at Keanakāko'i. There is an historical trail that extends through this area, and the map delineates this trail as providing a linkage between all of these elements (See Figure IX-4). The cultural landscape is thereby preserved within the Science Reserve and to the NAR, in a manner where people may experience the cultural resources of Mauna Kea in the traditional manner at the 13,000 ft. elevation without interacting with the modern astronomy facilities. Simulated views from Wai'au are shown in Figure IX-5.

GIS Mapping of Natural and Cultural Resources

Unique Surface Geology. There are numerous unique areas of surface geology within the Science Reserve, including cinder cones, glacially scoured rock surfaces, glacial moraines, rock structures formed by sub-glacial eruptions, texturally sorted soils, and an alpine lake. Outcrops of uniquely fine-grained, dense lava found along sub-glacial vents and lava/ice contacts within the Mauna Kea Ice Age Natural Area Reserve and adjacent areas were extensively used as quarries (Keanakako'i) for ancient Hawaiians to obtain adze materials. The distribution of these features is shown in Fig IX-6. These areas are included in the GIS as unique geological resource areas, and will be protected from disturbance by development and intensive recreational activities. Slopes in excess of 20 percent are shown in Figure IX-7.

Flora Habitat. Flora species distribution within the Science Reserve relate directly to the surface geology character. Lichens and ferns occur strictly where there are craggy andesitic lava outcrops to provide shade, some soil (ferns), physical protection and moisture collection. Mosses are more widely distributed on rock mounds across the upper slopes. GIS mapping of flora resources shows the general extent of lichens and ferns. As shown in Figure IX-8, areas of concentration of lichen habitat are identified within the andesitic lava flows to the north and west, with the more limited fern habitat on the slopes to the north of the summit (Char, 1999, 2000).

Flora species could be affected by the construction of new paths, roads, and facilities. The natural habitat for concentrations of the unique floral resources of lichens and ferns found in the summit region will be protected in the plan. Site specific surveys would be needed to determine siting choices to minimize effects upon sensitive flora habitat. Selective replanting/reintroduction of silversword is proposed for the cinder cones within the Science Reserve. Upper slope flora species that could also be reintroduced upslope from their current distribution include *pūkiawe* and *'ōhelo.*



Archaeology

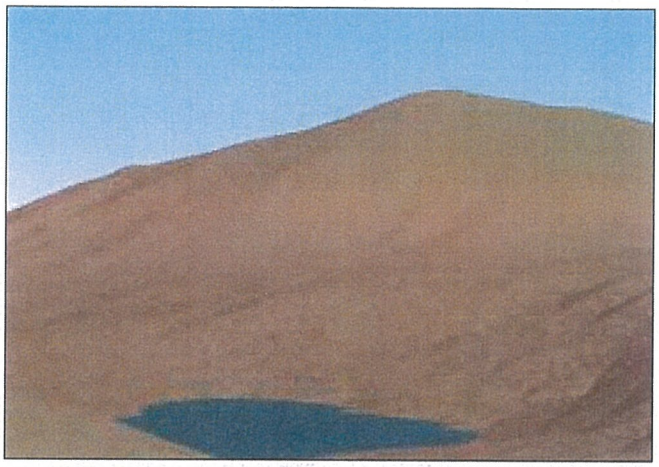
- Shrines
- Marker
- Unknown
- Workshop

- 25' Contour Intervals
- Band of Archaelogical Sites at 13,000 ft. elev.
- Historic Trail Linking Cultural Resources
- Undeveloped Pu'u

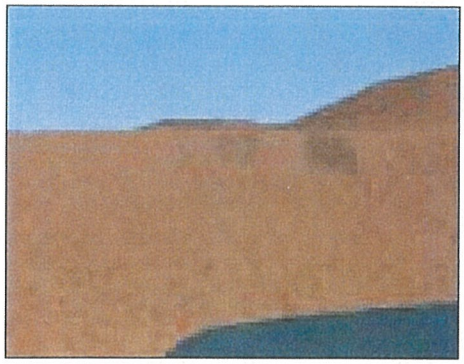
0' 2000' 4000' 8000'

NORTH

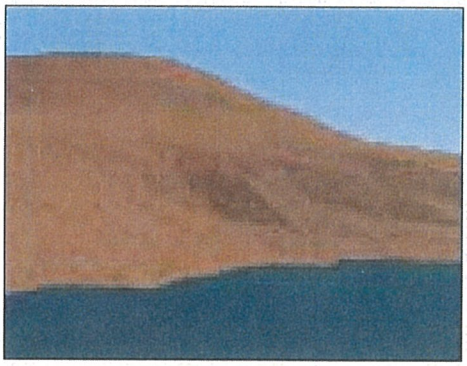
Existing Trail Linking Hawaiian Cultural Resources



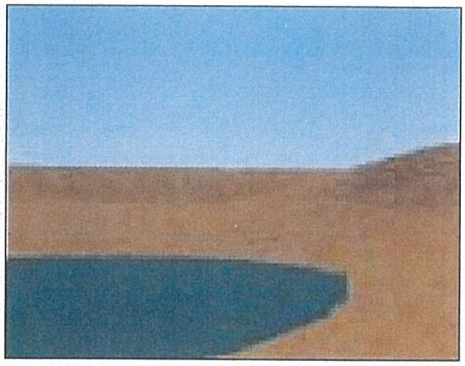
View of Pu'u Poli'ahu



View North

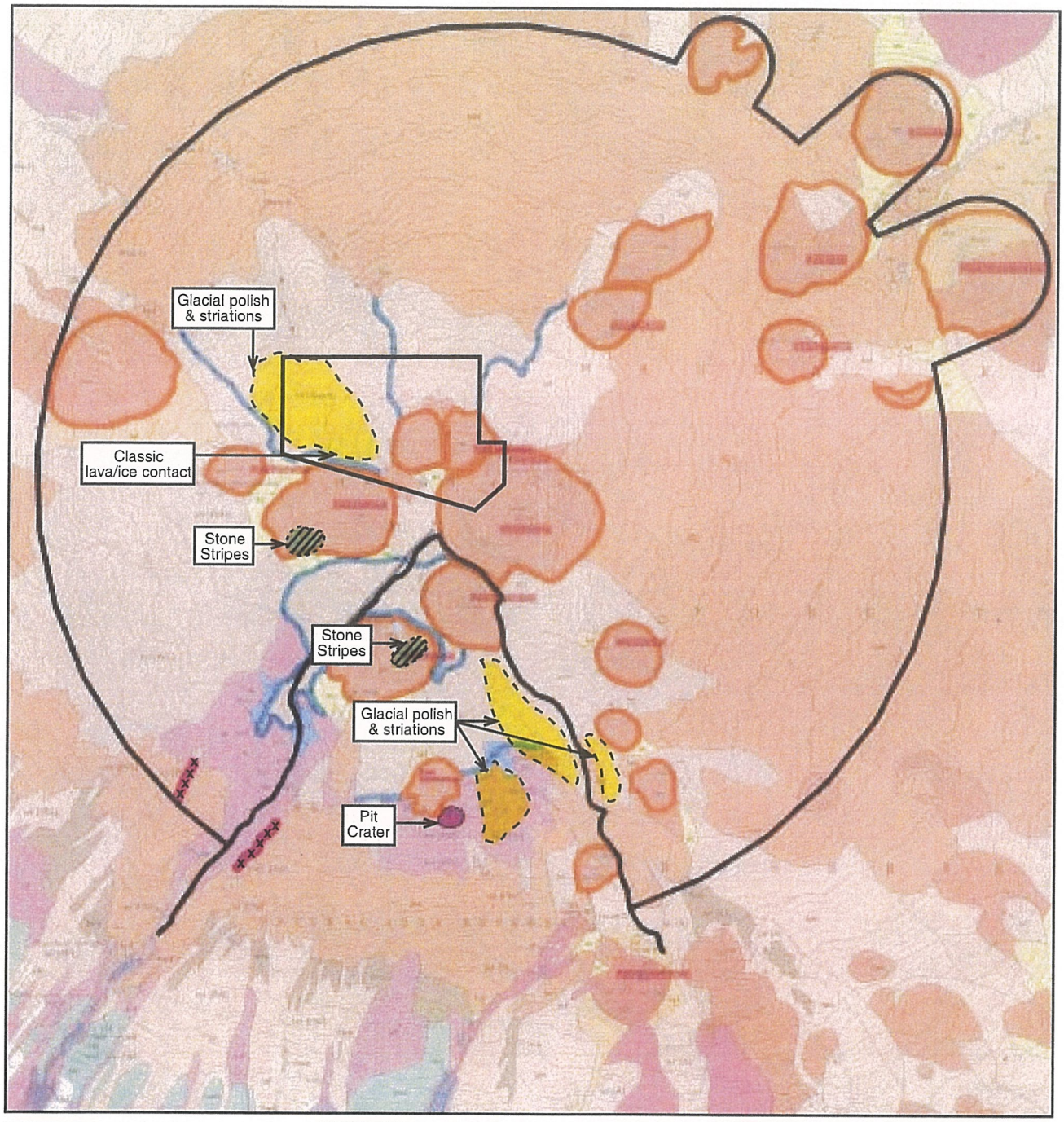


View of Pu'u Hau Kea

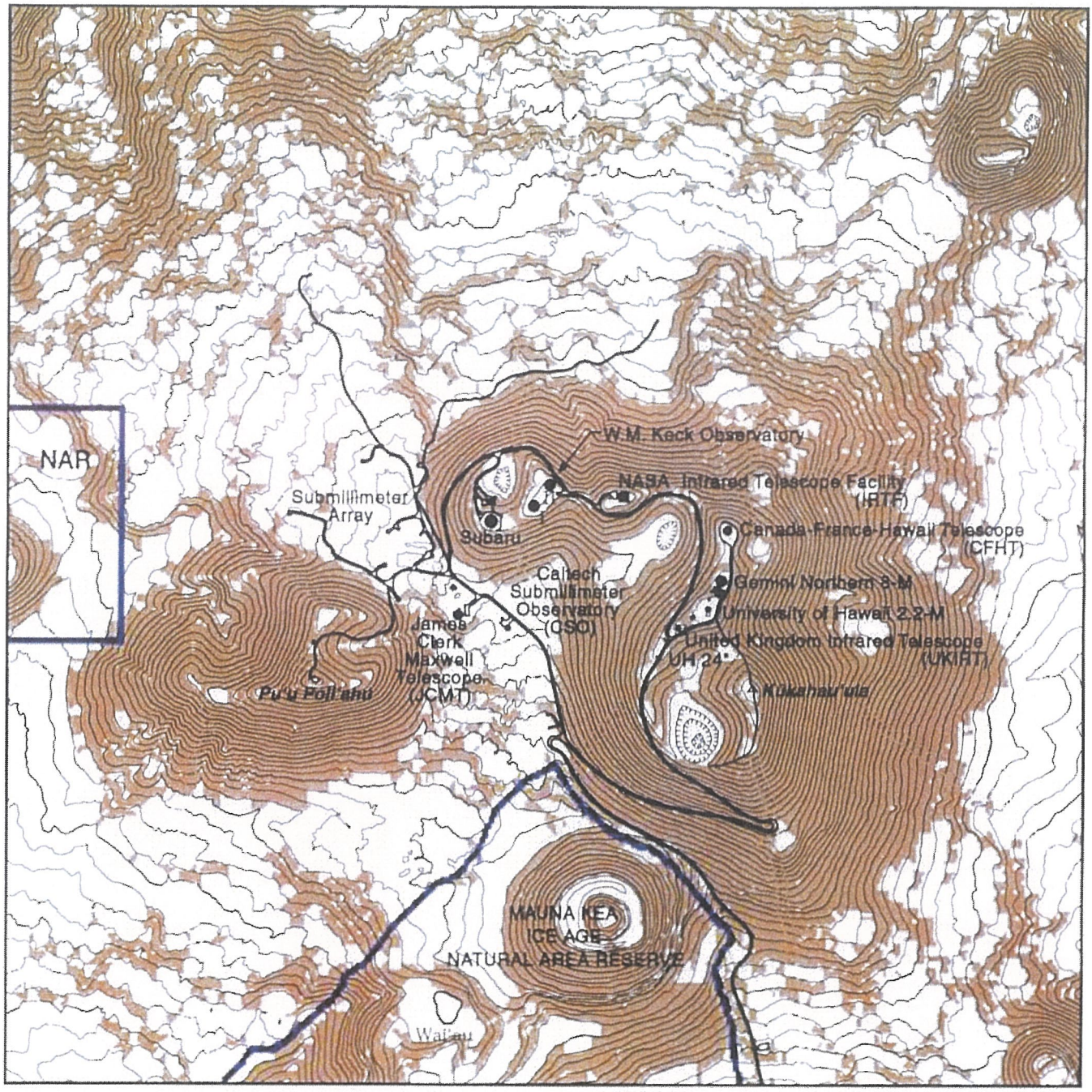


View of Pu'u Wai'au

Simulated Views from Wai'au



Source: Lockwood (January 2000) Generalized map of the Mauna Kea Science Reserve, showing the locations of geologically unique features.



Source: R. M. Towill Topographic Survey, 1997
Group 70, Slope Analysis, 1998

Slope 20% or Greater

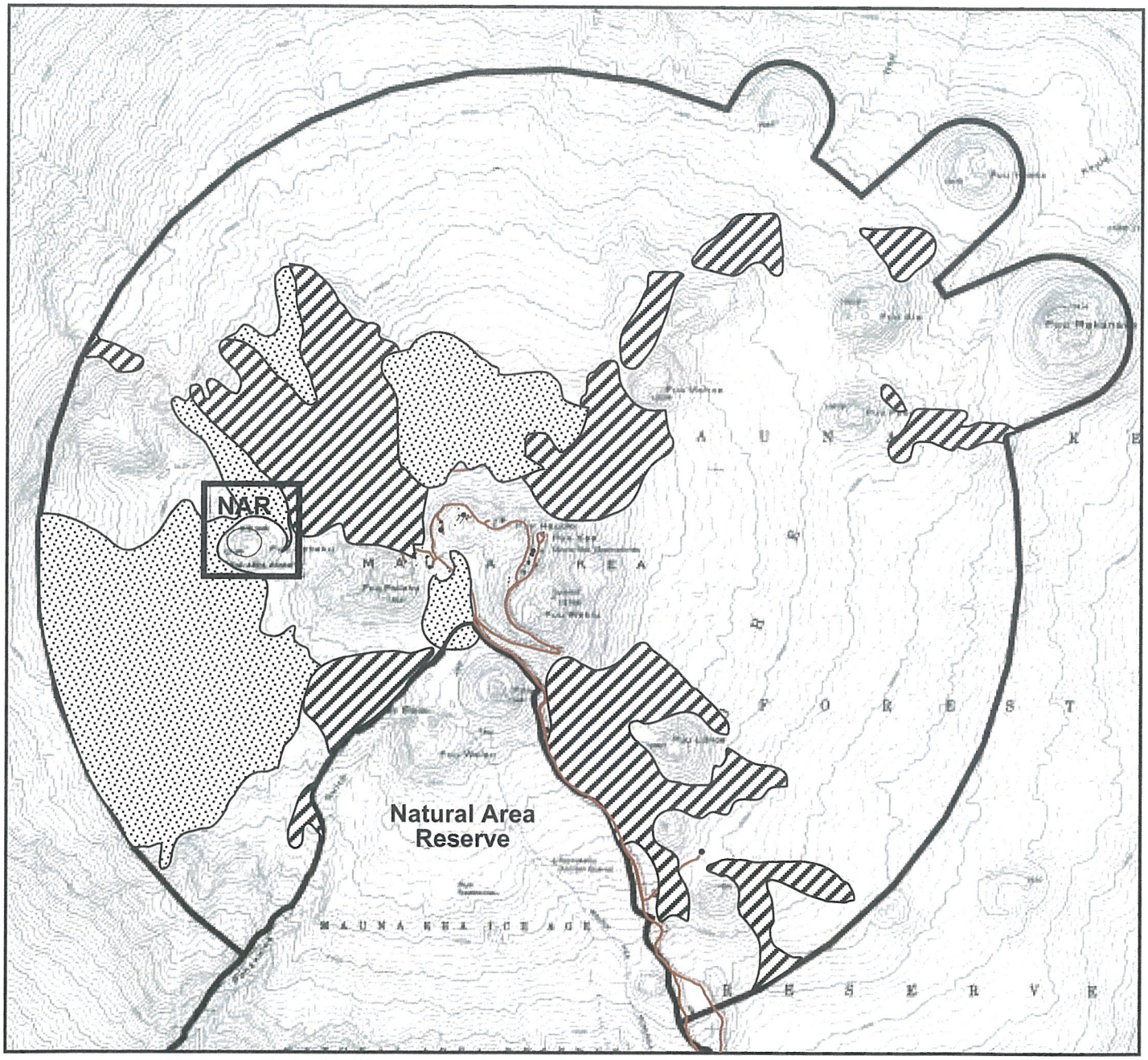
25' Contour Intervals

Natural Area Reserve

0 750' 1500' 3000'

NORTH

Slope Analysis



40' Contour Intervals

Potential *Cystopteris* fern habitat

Potential lichen habitat

Source: Winona Char, 1999
Note: Mosses are found throughout the summit area, primarily on rock outcroppings with crevices and fissures.

0' 2000' 4000' 8000' NORTH

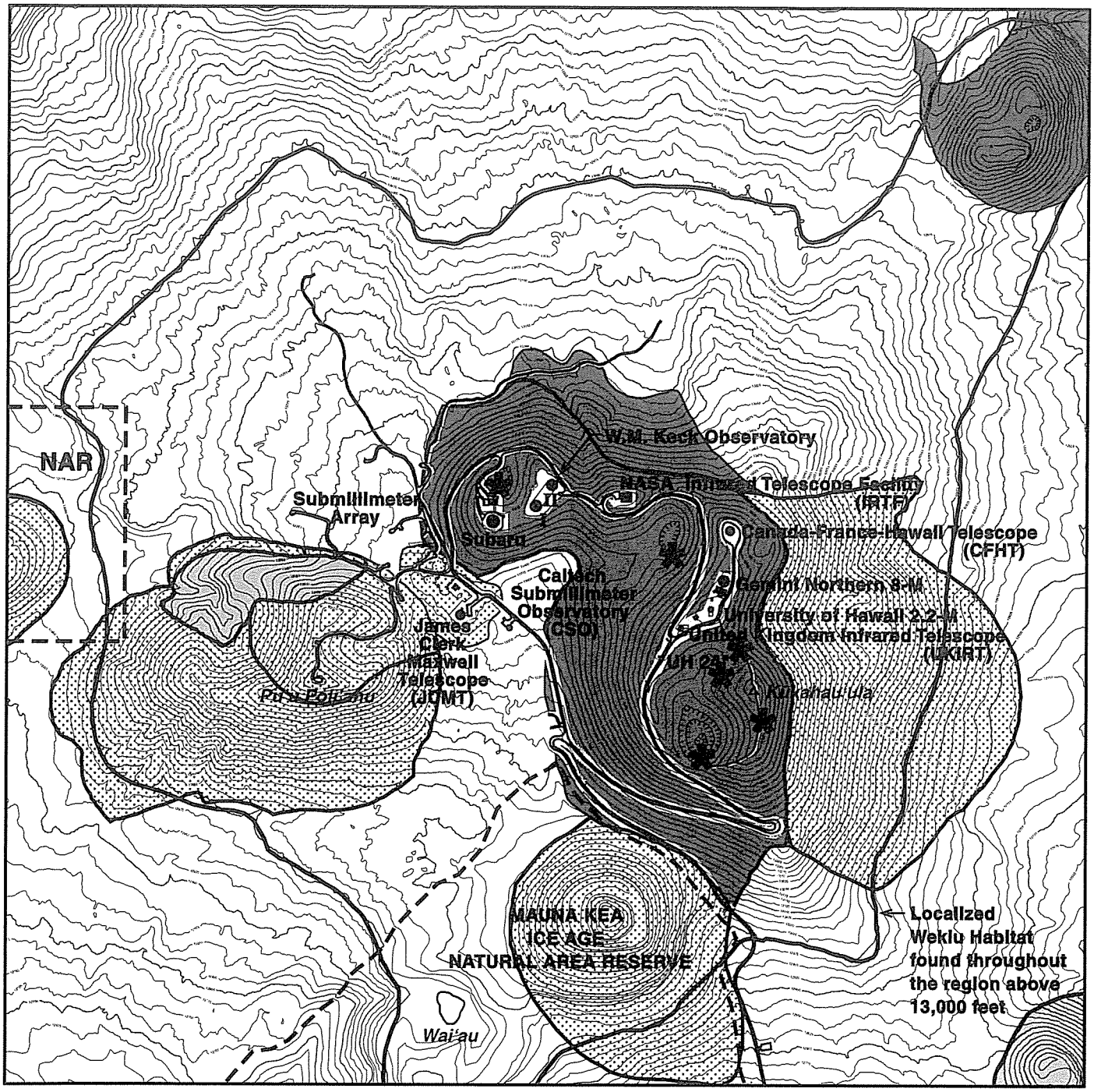
Summit Flora Habitat

Fauna Habitat. Arthropod distribution on the upper slopes of Mauna Kea relates directly to the surface geology. The Wēkiu bug *(Nysius wēkiucola)* is found primarily in the undisturbed cinders of the large cinder cones at Mauna Kea's summit, as shown in Figure IX-9. Other arthropod species such as the Lycosid wolf spider and Noctuid moths are more widespread within the Science Reserve. Lower elevation areas on Mauna Kea, outside the Science Reserve, include faunal components relating to the *māmane* and *naio* forest ecosystem.

GIS mapping shows the extent of areas of Wēkiu bug concentration, including areas with documented presence of the bug and areas of suitable habitat. The Master Plan will minimize disturbance of the cinder cone habitat for the Wēkiu bug within the Science Reserve. Expansion or redevelopment of existing sites on the summit ridge will have contained localized effects to the cinder cone habitat in the immediate vicinity of the older telescopes. As a result of the overall preservation measures, the habitat of the Wēkiu bug in the Mauna Kea Science Reserve will be protected. A composite of natural resources in the summit area is presented in Figure IX-10.

Archaeological Resources. Archaeological sites are found in the upper slopes of the Science Reserve, yet sites are virtually absent in the proximity of the summit *pu'u*. Shrines are clustered around the summit at approximately the 13,000 ft. elevation. Refer to Section V for more detailed information about archaeological sites. The clustering of sites appears around Lake Wai'au and the adze quarry in the NAR, at site complexes adjacent to the summit access road, and large numbers of shrines on the north slope at the edge of the plateau around the 13,000 ft. elevation. A consistent pattern was found, suggesting that shrines were erected by Hawaiians travelling up the mountain as tributes to their deity. Based on the field research, archival studies and oral histories, there are no burial sites in the vicinity of the summit *pu'u*. The plan preserves the areas near the higher concentrations of archaeological sites, restricting these areas from future development and most activities. Figure IX-11 shows the extent of archaeological sites.

Cultural Properties/Landforms. Culturally-significant landforms and places at Mauna Kea have been identified based on interviews and historical archival research. Refer to Section V for more detailed information about the cultural setting. A Cultural Landscape Map is presented in Figure IX-3. The Master Plan avoids adverse effects to cultural properties/landforms. The area of critical cultural importance encompasses the area of Poli'ahu to Wai'au to Kūkahau'ula at the summit. The *pu'u* within the summit region are the natural cultural landscape of Mauna Kea, with a visual linkage to the area of the sacred alpine lake at Wai'au and the adze quarry at Keanakāko'i. Preservation of the major *pu'u* of the summit in an unaltered state is essential to retaining their cultural significance, and will retain the integrity of vistas and site relationships. This approach is consistent with the perspective taken by the Historic Preservation Plan DLNR (March 2000), that Mauna Kea's numerous shrines and culturally significant landforms along the upper slopes altogether constitute an historic district.



Source: Dr. Frank Howarth, Bishop Museum, 1999

Likely Habitat/Specimens Found

Likely Habitat

Likely Habitat/Presence Unknown

25' Contour Intervals

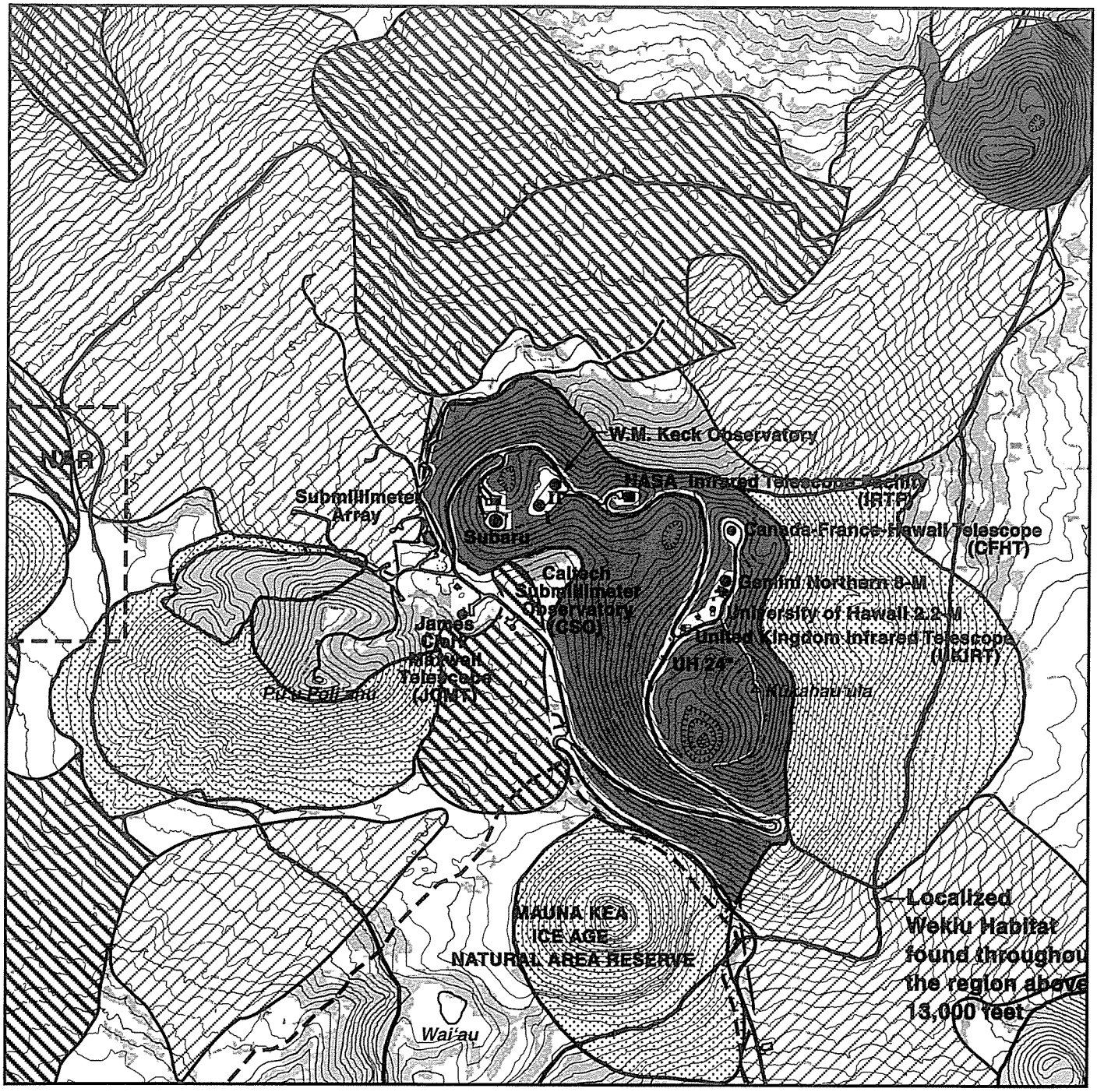
Natural Area Reserve

Specimens Found 1997-1998

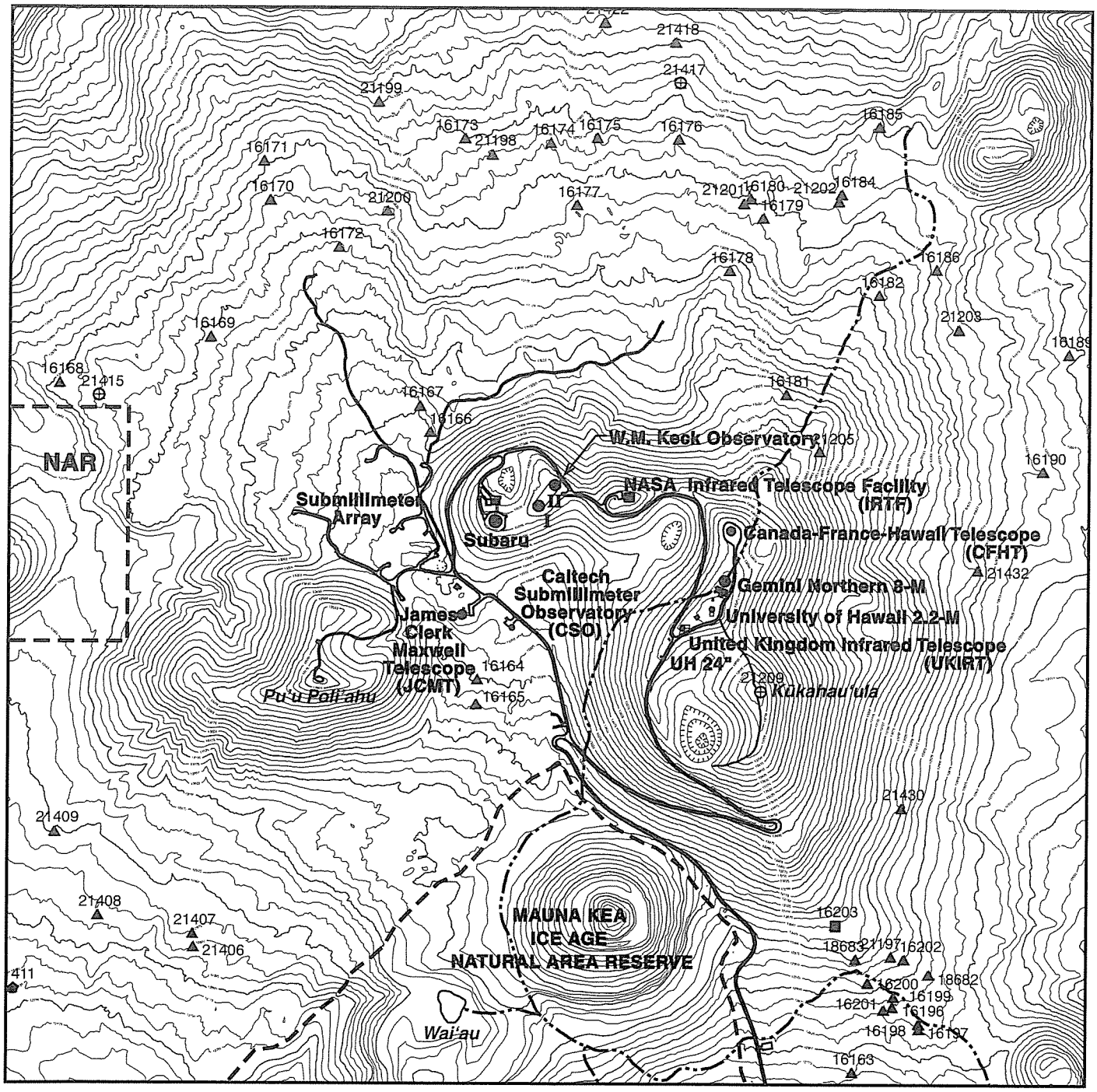
0' 750' 1500' 3000'

NORTH

Potential Wēkiu Habitat



Natural Resource Composite



Source: Hawaii Department of Land and Natural Resources
Historic Preservation Division, Feb. 1999

Archaeology Sites Map

Summary of the Natural and Cultural Resources Physical Planning Guide. The plan provides a clear future direction toward preservation of natural and cultural resources, by directing proposed new development to locations within the summit region where the resource values would not be diminished. A Natural and Cultural Resources Composite map is presented in Figure IX-12. Since these resources are physically adjacent, they are planned and managed together in a living, evolving and sustainable approach. Traditional access to the resources for cultural practitioners is unimpeded, as long as laws are not violated. Natural resources will be preserved consistent with a growing interest in the restoration of the overall mountain ecosystem. The relationship to existing plans and laws regarding natural and cultural resources is addressed in the environmental review (EIS) process.

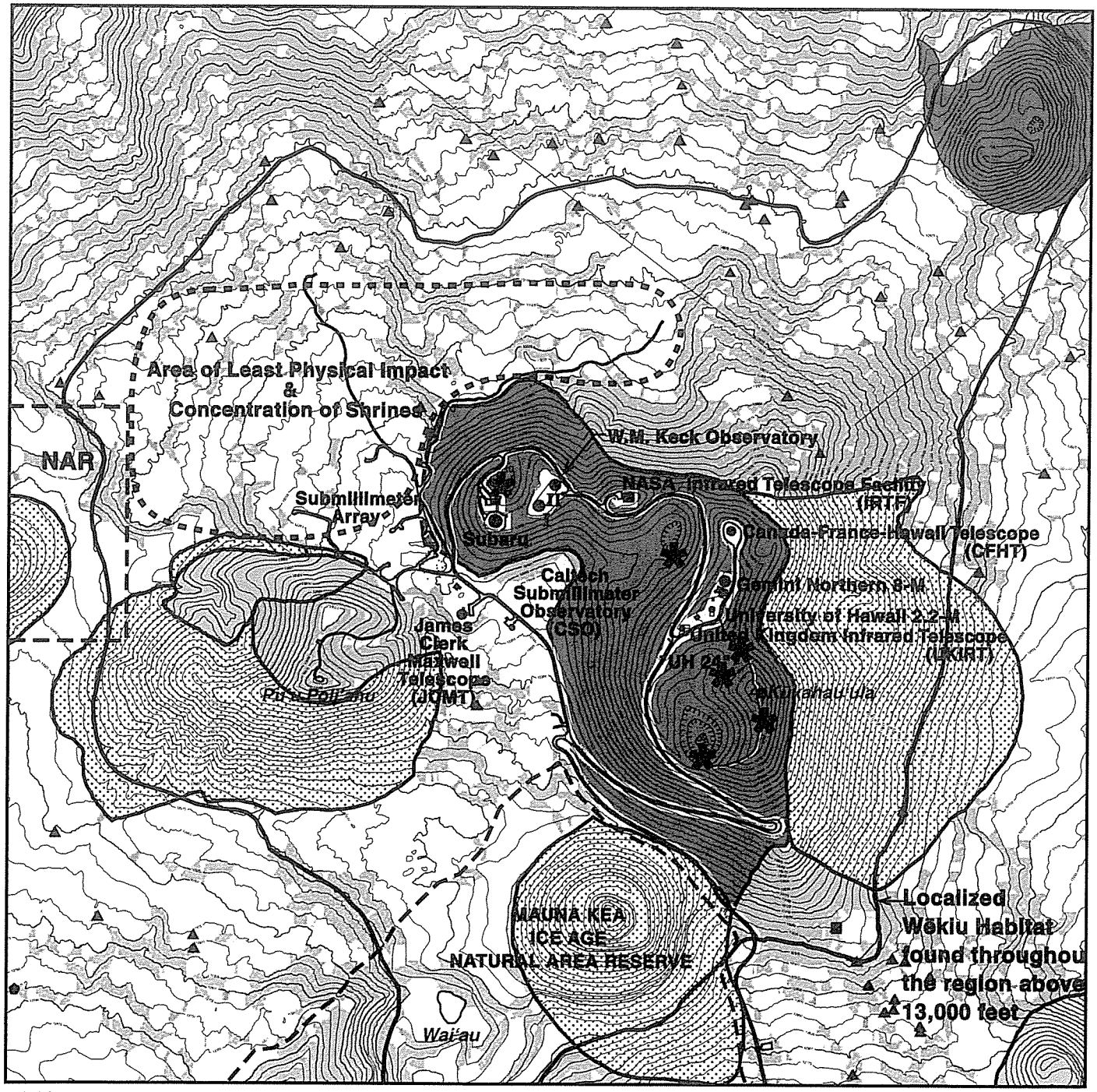
EDUCATION AND RESEARCH COMPONENTS

Mauna Kea has long enjoyed a revered place in native Hawaiian culture, in the lives of those who live on its slopes and all who come in contact with this, one of the world's tallest mountains. Study and research of the cultural and natural features of Mauna Kea are integral to contemporary use of Mauna Kea. Mauna Kea is also the world's premier astronomical research location, and astronomy on Mauna Kea is an essential element of Hawai'i's economy and high technology future. The evolution of astronomy technology, and world-wide interest in astronomy research at this location, presents a current need to upgrade and expand telescope facilities. However, since the time the first telescopes were proposed on Mauna Kea, there have been differing viewpoints about astronomy development, as discussed in the previous section. There is a concern that astronomy development has been distributed across the summit in an unattractive fashion, and that this development might eventually overtake the mountain. There also are concerns about the potential impacts of development to natural resources, such as the Wēkiu bug habitat, archaeological sites and Hawaiian cultural resources.

The education and research component is the second integration of the physical planning guide, which joins the projected education and research uses with the natural and cultural resource component. The natural and cultural resources map identifies the preservation areas where resource values are highest, and development activity is guided elsewhere.

Overall objectives for education and research:

1. Expand knowledge of the Science Reserve as an educational resource for the benefit of the community, students, researchers, and visitors, through the planning process.



Wēkiu

- Likely Habitat/Specimens Found
- Likely Habitat
- Likely Habitat/Presence Unknown
- Specimens Found 1997-1998

Archaeology

- Shrines
- Marker
- Unknown
- Workshop

- 25' Contour Intervals
- Natural Area Reserve
- Slope 20% or Greater

0' 750' 1500' 3000'

NORTH

Natural & Cultural Resources Composite

2. Protect natural and cultural resources and insure managed access to the Science Reserve for education and research use.

3. Protect and enhance astronomy research at Mauna Kea as it is the premier observatory site in the Northern Hemisphere.

4. Define areas, criteria and support facilities for education and research as applicable, to allow for sustainable, integrated planning and management.

Astronomy Precinct

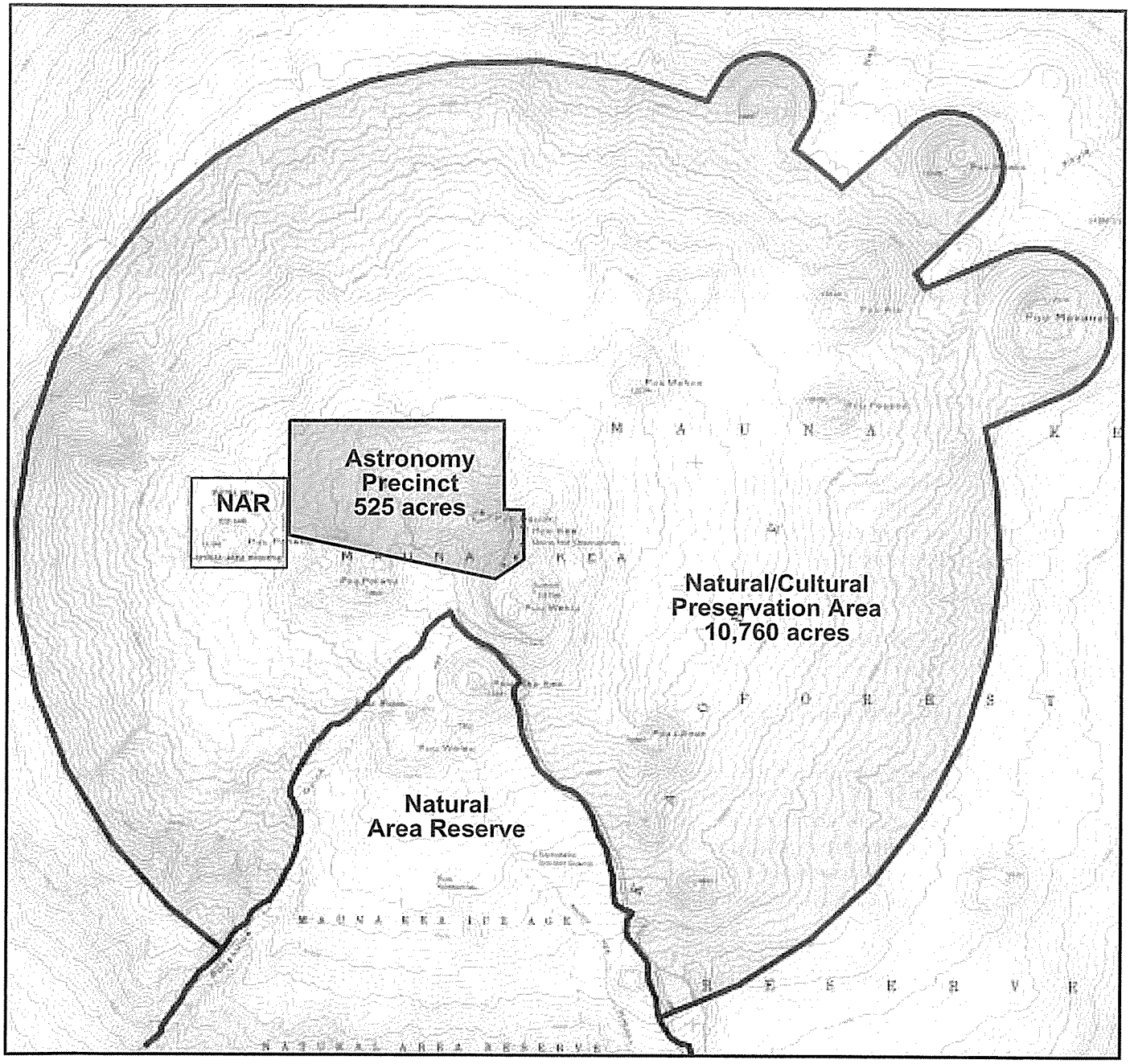
An "Astronomy Precinct" is defined where development will be consolidated to maintain a close grouping of astronomy facilities, roads and support infrastructure. This approach minimizes the potential impact to the natural and cultural resources of the summit region. The criteria to be followed for new facilities proposed in the Astronomy Precinct include:

- Emphasize the recycling of existing sites so as not to disturb existing habitat areas, archaeology and landforms;
- Limit visual impact and scattering of facilities by clustering within the existing development area, recognizing that facilities have already been built in this area and presently have a visual impact;
- Utilize the natural forms in the summit area to shield views of built facilities, from both off-mountain and atop this mountain;
- Implement design measures to allow facilities to blend in better with the natural landscape, to minimize the sense of disruption to the landscape; and
- Minimize infrastructure development by locating near the existing roadway and utility network.

As shown in Figure IX-13, the Astronomy Precinct is defined by the limits of the critical resource areas identified within the natural and cultural resources component of the Master Plan, as well as by considering the siting needs of future astronomy facilities. The Astronomy Precinct will be approximately 525 acres, or less than five percent (4.65%) of the existing Science Reserve. The boundaries of the Precinct have been established based on the following resources:

- Northern boundary: The boundary to the North avoids clusters of archaeological sites (shrines) found at the 13,000 ft. elevation, providing a minimum 200 ft. setback. This setback distance is 10 times the setback distance required by the Hawai'i Island Burial Council for development near existing burials.

- Eastern boundary: The Eastern slope of the summit is a broad natural area, with no development at present and which is highly visible from the Hilo area. This will ensure no development on this slope.



Astronomy Precinct

- Southern boundary: The culturally significant places of Poli'ahu and Kūkahau'ula, and the intervening area between Poli'ahu and Wai'au, set the Precinct limits to the south. This also respects the Wēkiu bug habitat associated with the summit cinder cone. The precinct boundary also retains an open view from Kūkahau'ula toward the western slope of Mauna Kea, which some have identified as a potentially important resource of cultural and religious significance.

- Western boundary: The NAR and Pu'u Pōhaku and steep slopes set the western limit.

Included within the Astronomy Precinct are three shrines out of the 93 archaeological features which have been identified in the Science Reserve. The Precinct includes relatively flat areas, and the potential development locations within the Precinct are largely shielded from Wai'au and the existing roads. In addition, the implementation of design guidelines outlined at the end of this chapter will minimize the visibility of proposed new astronomy facilities within the Astronomy Precinct.

Astronomy Precinct Detailed Plan - Siting Criteria. Specific siting criteria have been set for locating new facilities within the Astronomy Precinct. These criteria include:

1. Minimal impact on existing facilities. Existing astronomy facilities require a clear line of sight to approximately 12 degrees above the horizon in a full circle. The location of proposed new facilities cannot obscure the observation function of the existing telescopes on the mountain. Proposed new facilities must be spaced accordingly within the Astronomy Precinct.

2. Minimum impact of Wēkiu bug habitat. The major pu'u in the area of the summit all possess confirmed or likely habitat for Wēkiu bug where the cinder cone surface geology is present. Only the existing disturbed locations on pu'u or areas outside of the Wēkiu bug habitat will be considered as potential siting areas.

3. Avoidance of archaeological sites. There are three existing archaeological shrines within the Astronomy Precinct, and these sites must be avoided in future facility siting. In addition, any new facilities will be set back at least 200 feet from the clustered group of shrines found outside the Precinct boundary on the northern slope. This setback distance is 10 times the setback distance required by the Hawai'i Island Burial Council for development near existing burials.

4. Suitability for Observations. Potential sites for new observatories within the Astronomy Precinct must meet specific standards for conducting astronomical observations, including acceptable obscuration and wind flow conditions.

5. Minimum visual impact from significant cultural areas. Views from the pu'u and archaeological sites will be respected in the siting of future facilities. The location of new facilities will avoid interference with the visual connections between the major pu'u and the shrine complexes.

6. Avoid or minimize views from Waimea, Honoka'a and Hilo. Sites for proposed new facilities will maximize the use of the existing topography to shield views from the downslope communities. Prominent sites along the ridges or pu'u will not be selected for new development of astronomy or other research and education facilities.

7. Close to roads and existing infrastructure. Sites for proposed new development will be selected close to the existing roadways to minimize the amount of disturbance to the natural terrain. Utilities and communications service to new sites will be extended along the existing roadway routes to minimize disturbance.

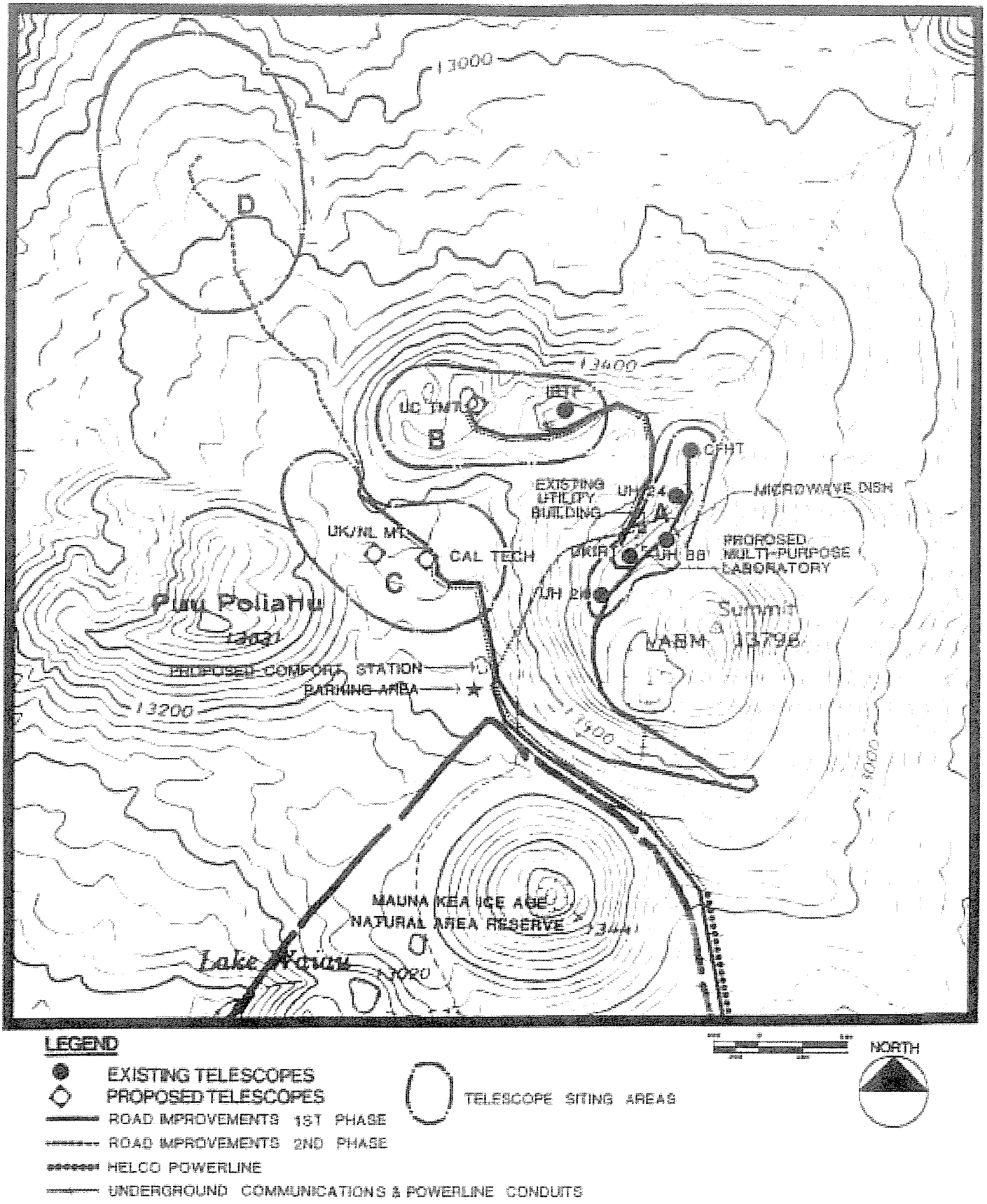
Astronomy Precinct – Telescope Siting Areas. The 1983 plan included seven areas in the Science Reserve that were designated as Analysis Areas, as shown in Figure VIII-3. Of these seven areas, four areas (A-D) were designated as Telescope Siting Areas. There was an ample allocation of space in each of the 1983 Siting Areas, to allow for flexibility in the siting of telescopes that had yet to be designed and built on the summit.

The total area allocated in the 1983 plan for telescope siting in the four areas totaled approximately 160 acres. All of the existing observatories and anticipated new facilities in the 1983 Plan were to be sited within these four areas, as shown in Figure IX-14. Only the Siting Areas A, B and C have been utilized for observatory development up to this point.

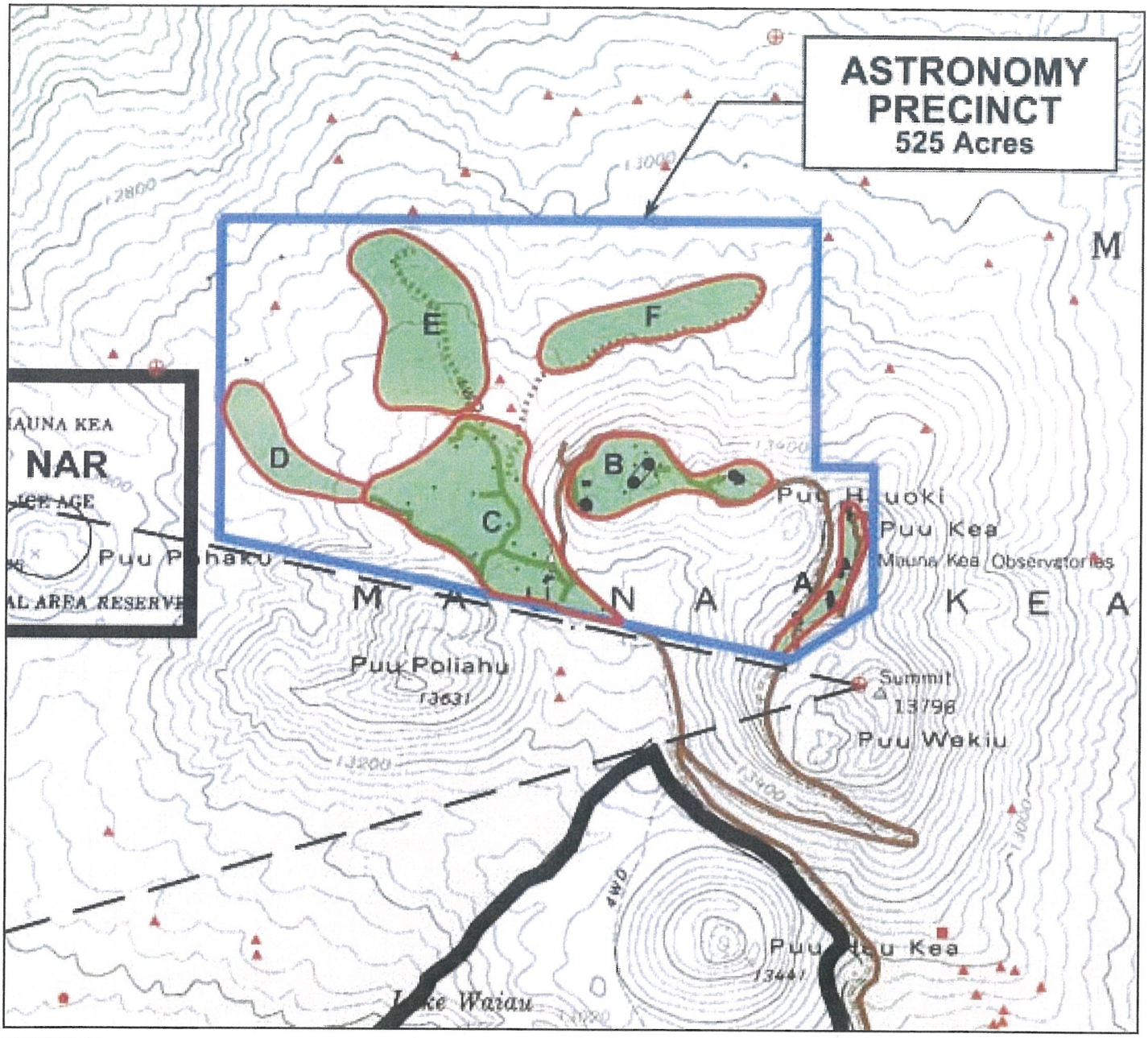
The update of the Master Plan enables the refinement of the Telescope Siting Areas within the Astronomy Precinct, to include all existing observatories, proposed redeveloped facilities and new facility sites. Proposed Telescope Siting Areas (2000-2020) are shown in Figure IX-15, consistent with criteria described above.

Siting Areas A, B and C are already developed with observatories. All the instruments proposed in the previous plan are constructed, and the limits of these observatory sites define Areas A, B and C. There is little area available for new telescope development in these three siting areas, however, redevelopment of existing facilities would be possible.

Within the Astronomy Precinct, new telescope siting areas were identified consistent with the siting criteria described earlier. The areas which are anticipated to provide suitable observation conditions with minimum impact on existing facilities, wekiu bug habitat, archaeological sites and minimal visual were selected as the new telescope areas D, E and F, as delineated in Figure IX-15. Each expansion area is linked to the existing unpaved roads, which minimizes disturbance to the natural terrain. In the new plan, Areas D and E are expansion areas that are located in the vicinity of Area D from the 1983 plan; however, the new Areas D & E will avoid sensitive shrines that were previously located in the siting area. Area F is located in the vicinity of an Analysis Area V from the previous plan (Figure VIII-3).



Telescope Siting Areas (1983)



40' Contour Intervals

A-F Telescope Siting Areas

Telescope Siting Areas (2000-2020)

Compared to the 1983 Telescope Siting Areas, the current plan reduces Areas A and B, reconfigures Areas C and D, and adds Areas E and F. The current Master Plan reduces the total area allocated for Telescope Siting Areas to approximately 150 acres, as compared to approximately 160 acres in the 1983 plan.

Telescope Siting Areas (1983 Complex Development Plan)		**Telescope Siting Areas (Updated Master Plan 2000-2020)**	
Area Designation	**Approximate Area (ac.)**	**Area Designation**	**Approximate Area (ac.)**
A	18	A	10
B	34	B	22
C	35	C	43
D	75	D	16
		E	36
		F	23
Total	**162**	**Total**	**150**

Astronomy Precinct - Definition of a Telescope. The 1998 report by the State Legislative Auditor recommends departing from the simplistic counting of "telescopes" at the Mauna Kea Science Reserve. To help clarify the issue of counting telescopes, it is appropriate to examine the definition of a telescope. Webster defines "telescope" as follows: *An instrument for collecting and examining electromagnetic radiation.* This is consistent with the working definition for telescopes within astronomy. A telescope must have the capacity to *collect* as well as *examine* visible light and/or invisible radiation – i.e., it must be capable of making astronomical observations.

By this definition, Keck, Gemini, Subaru, Canada-France-Hawaii, both U.H. facilities, UKIRT, JCMT (Maxwell), VLBA, and Caltech are telescopes. The Submillimeter Array (SMA), when taken as a whole, is a telescope, but not each antenna. Each antenna collects radiowaves, but is not capable of providing astronomy observations. If a control building were attached to each antenna, then these antennas would be considered telescopes. The control buildings would, of course, be larger than the antenna. In the same way, the proposed 4-6 Keck outriggers are collectors which are part of an interferometer and not individual telescopes. When connected to the control building within the existing Keck, they would form one interferometric telescope.

An analogy for an array telescope is a stereo system. Each speaker is not a stereo system in itself but all the components make up one system. Each part is considered a component with a specific name and purpose. The use of the term "stereo" to refer to a speaker, receiver, tape deck, etc. is inappropriate. In the same way, the use of the term "telescope" for components is inappropriate.

The approach taken by the Master Plan is to describe the actual components of proposed astronomy development. This approach provides for full disclosure to the extent possible when viewing the future of astronomy facilities atop Mauna Kea, and is consistent with the Auditor's recommendation to get away from the simplistic counting of "telescopes".

Astronomy Precinct - Anticipated Program for Astronomy Development. The projected expansion of astronomy research facilities at Mauna Kea is specified in the Institute for Astronomy's Research Development Program (2000-2020), which is included in Appendix A. The anticipated program for astronomy development envisions five different categories of facility development projects (Types I-V), as listed below.

Type I. Redevelopment of Existing Observatory Sites on the Summit Ridge:
Redevelopment or "recycling" of up to five existing telescopes, including NASA/IRTF, CFHT, UH 2.2 m, UKIRT, and UH 0.6 m. It is anticipated that up to three or four facilities may be redeveloped over the next 20 years.

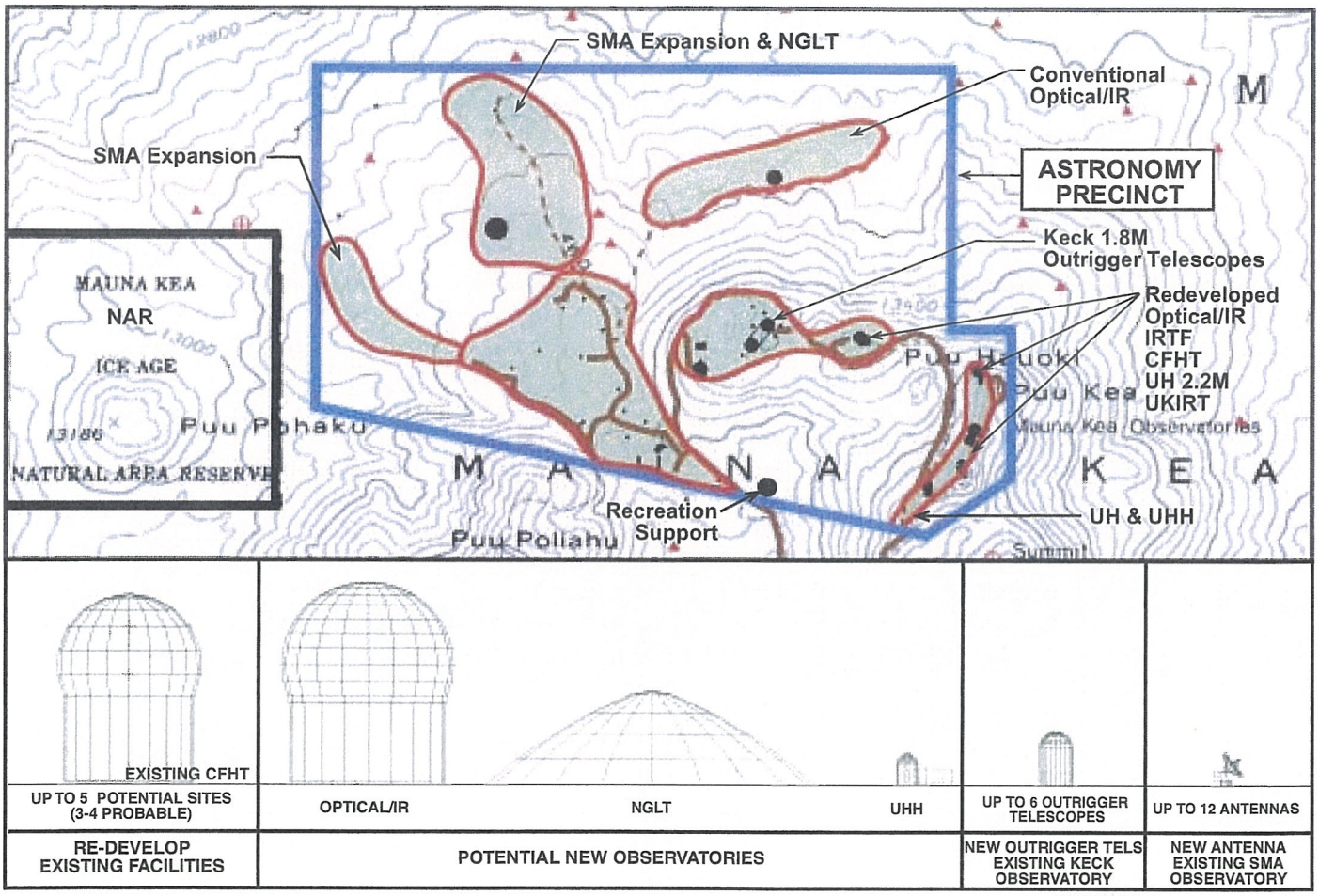
Type II. Expansion of Existing Observatories:
Expansion of the Keck Observatory with the addition of four to six 1.8-m. outrigger telescopes. Four are being proposed to start development in 2001. The Submillimeter Array may add up to 12 new antennas and 24 new pads over the next 20 years.

Type III. New Conventional Optical/IR Telescope
A new conventional telescope comparable to the Keck or Gemini Observatories at a currently undeveloped site. An instructional telescope for UH-Hilo is also projected.

Type IV. Next Generation Large Telescope (NGLT)
A single optical/IR telescope of 25 m. aperture or greater. This is currently only being discussed in the astronomy community and there is a 50 percent possibility that this facility may be developed in the next 20 years.

Type V. Optical/IR Interferometer Array Site
A general area is proposed for this observatory. No facilities are included in this Plan. Facilities must undergo the major Master Plan amendment process for approval.

Given the prescribed criteria for site selection, and UH's anticipated program for astronomy development in the next 20 years, specific sites or areas within the Astronomy Precinct have been identified. A summary of all proposed research facilities development in the Astronomy Precinct is presented in Figure IX-16. An expanded discussion of each of the proposed facility type and locations is presented below.



Physical Plan and Proposed Astronomy Facilities

Type I. Redevelopment of Existing Observatory Sites on the Summit Ridge.

The most likely type of astronomy development at Mauna Kea would be the replacement or upgrading of facilities at existing sites, as a first preference, or the development of new sites as a second preference. It is expected that the proposed new or upgraded conventional optical/IR telescopes will come in a range of sizes, from 2 to 15 m. mirror sizes. The 10 m. mirrors of the existing Keck, Gemini and Subaru telescopes represent the current state-of-the-art instrument.

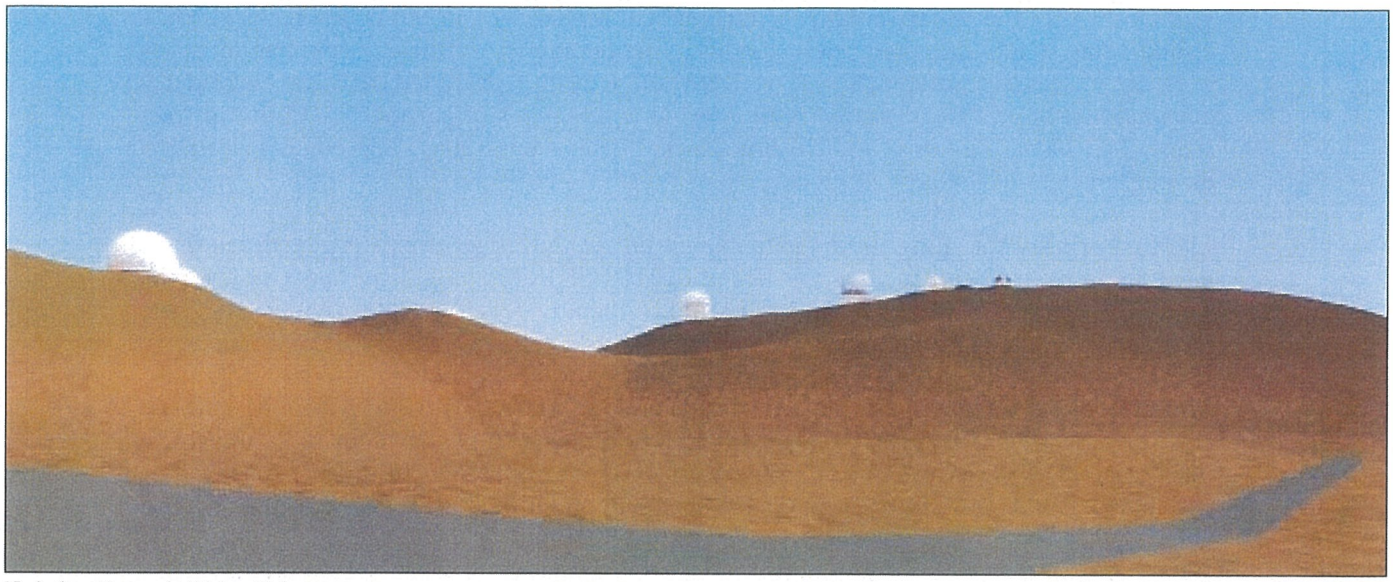
The first priority for siting these facilities will be the recycling of existing facilities that have aging technology, such as the IRTF, CFHT, UKIRT, UH 2.2 m. and UH 0.6 m. These five telescope sites have already been disturbed by development activities, and the facilities are part of the existing visual setting. The IRTF, CFHT, UKIRT, UH 2.2 m. and UH 0.6 m. are all over 20 years old, and the current technology for conventional telescopes is far superior. The present sites on the summit ridge are attractive for locating new or upgraded facilities because of known high quality locations and existing infrastructure. Most of the existing observatory organizations may be unable to operate both a new facility and the existing one, so they will prefer to recycle their existing site.

We expect to see a trend toward specialization for these conventional-size optical/infrared telescopes. For example, one facility may decide to concentrate on wide-field imaging, while another focuses on using adaptive optics to achieve the highest possible angular resolution over a small field. Specialization will allow the telescope facility to achieve the ultimate in performance within the chosen area of research, while at the same time simplifying the operation and thereby reducing costs. Specialization will provide a strong incentive for joint operating arrangements and shared use among the observatory organizations.

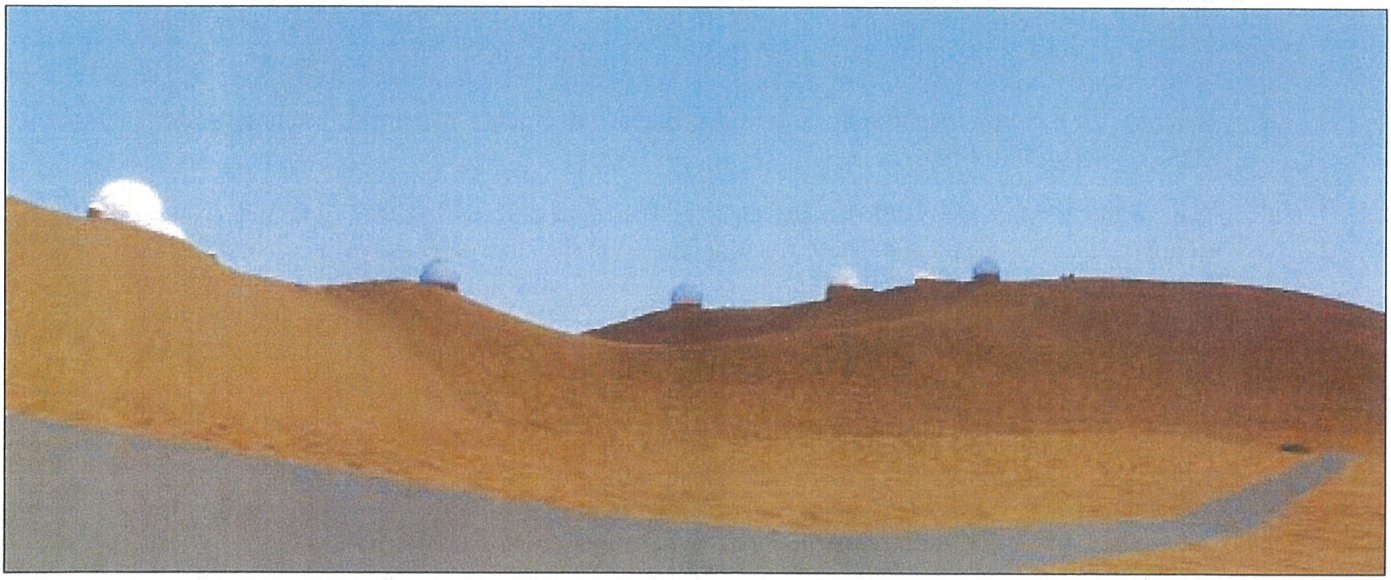
During the 20-year period of this Master Plan, it is expected that there may be proposals to upgrade or replace each of these five telescopes on the summit ridge with conventional optical/IR telescopes. Over the next 20 years, it is estimated that only three or four ridge facility upgrades will actually be constructed over this time period, including the replacement of the UH 0.6 m. telescope with a facility in the 2 to 3 meter mirror size range.

In addition to the replaced/upgraded conventional optical/IR telescopes on the ridge, UH-Hilo plans to construct an instructional telescope (1 m. mirror) adjacent to the existing UH 0.6 m. telescope on the existing site of a utility/storage building. Use of the facility is anticipated to be primarily instructional, with research uses only for programs with substantial academic or other instructional content, or when the telescope is not needed for such programs.

Figure IX-16 identifies the sites with the greatest potential for upgrades, expansion or redevelopment. A perspective view is shown in Figure IX-17.



Existing Summit Ridge Telescopes



Redeveloped Summit Ridge Telescopes

Existing and Redeveloped Summit Ridge Telescopes

Future telescope redevelopment on the summit ridge will limit these facilities to a maximum height and diameter of approximately 130 feet, to limit the visual impact along the ridge. This standard is derived from the approximate dimensions of the existing Gemini and Keck class of telescope. For more specific standards for these facilities, refer to the design guidelines at the end of this chapter.

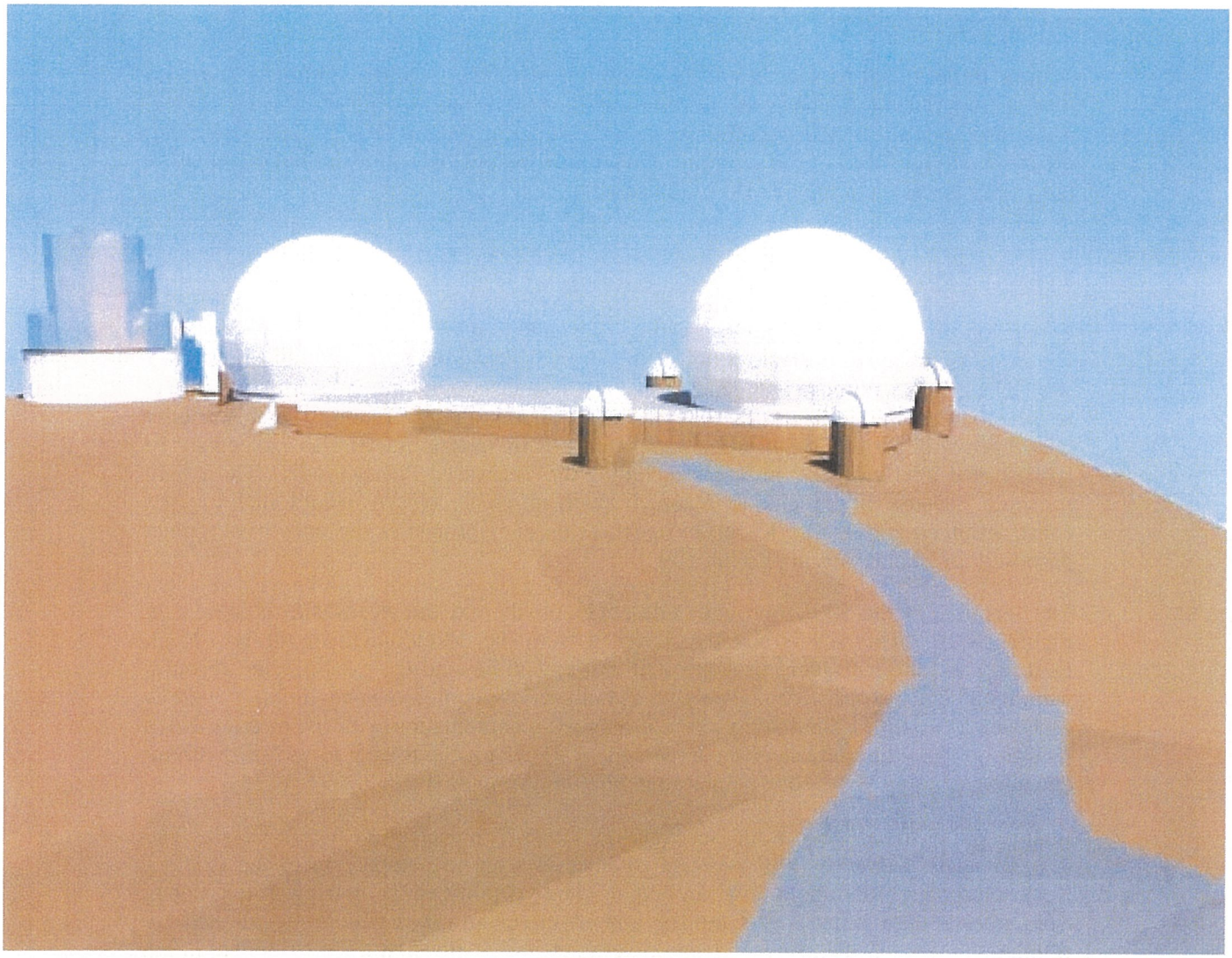
A three-dimensional perspective of the summit ridge under existing conditions and with recycled/upgraded telescopes, as viewed from the access roadway in "Millimeter Valley" near the James Clerk Maxwell Telescope, is included in Figure IX-17. The view from off-mountain locations of the summit ridge with the redeveloped conventional Optical/IR telescopes is shown in Figures IX-22, 23 and 24.

Type II. Expansion of Existing Observatories.

Expansion of the W. M. Keck Observatory. The addition of four to six 1.8-m. outrigger telescopes is planned to create a powerful infrared interferometer on the existing Keck site. The primary purpose is to study planetary systems around nearby stars. Funding is to be provided by NASA, with four of six outriggers already funded. The outrigger telescopes will test the feasibility and capability of IR interferometers, as a precursor to space-based interferometry missions including the Terrestrial Planet Finder. On a tight schedule because of its link to planned space missions, NASA would like to start construction in 2001. The Keck Outrigger Telescopes project is the only new project proposed for Mauna Kea at present.

The location of the Keck outrigger telescopes on the existing Keck site is shown in Figure IX-16. This site is already disturbed from the development of the two Keck facilities, and the outrigger telescopes will not extend beyond the existing site. From a natural and cultural resource perspective, the impact of the project is negligible. There is no better location for this facility since it requires a combination with the existing Keck facilities. The proposed use of the existing site allows for the project to be built without damaging existing Wēkiu bug habitat found in the surrounding area.

A three-dimensional view of the outrigger telescopes is presented in Figure IX-18. The new outrigger telescopes will be much smaller in scale in comparison to the existing Keck telescopes, only about 35 ft. in height. The visibility of the outriggers telescopes from areas at the summit is very limited, and off-mountain views will not be affected. A simulated view of the summit from off-mountain locations at Hilo, Honoka'a and Waimea, including the completed Keck outrigger telescopes, is shown in Figures IX-22, 23 and 24.



W.M. Keck Observatory with Proposed Outrigger Telescopes

Expansion of the Submillimeter Array (SMA). The existing SMA is anticipated to be operating in 2001. Within the next 20 years, it is likely there will be a need to expand the existing SMA, to include up to 12 new antennas and 24 additional pads. Some of these antennas may differ somewhat in size and structure from the current SMA antennas and operate independently of the others. This expansion will increase the sensitivity and angular resolution of the SMA and will allow for multiple studies to take place concurrently within a densified and elongated array.

Location issues involved with the submillimeter involve technical siting issues (slope and obscuration) and natural/cultural resource constraints. One of the potential array configurations, considered prior to this Master Plan, included the area to the south of the existing array, extending between Poli'ahu and Wai'au. Use of this area, however, would not fit with the natural and cultural resource component of the Plan. The inter-relationship between Poli'ahu, Wai'au and Kūkahau'ula (summit) is recognized as culturally significant, and the placement of antennas in the valley between these features would detract from this resource.

The expansion area will extend the baseline for this antenna complex approximately 0.5 km to the north and west of the existing array. Figure IX-16 shows the potential expansion area for the submillimeter array. A three-dimensional perspective view of the expanded submillimeter array is included in Figure IX-19.

The submillimeter array expansion will be concentrated in the area to the north of Pu'u Poli'ahu, and will not be visible from Hilo and Honoka'a. It will probably not be visible from Waimea, as shown in Figure IX-23.

Due to the relatively small size of the SMA antennas (25 ft. in height) they are virtually invisible from a distant perspective. To further diminish the visual impact of the SMA facilities, the concrete pads for the new antennas should be colored in a brown tone to match the surrounding lava/ash landscape. To the extent possible the SMA facilities will be sited to utilize the existing road and pathways.

Proposed Submillimeter Array Expansion

Type III. New Conventional Optical/IR Telescope

The second priority for siting proposed conventional optical/IR telescopes will be at a new site within the Astronomy Precinct, and only if a suitable summit ridge site cannot be utilized for redevelopment. In the event there is no existing site available, there is an area to the north of the summit ridge that could potentially support a new conventional optical/IR telescope. Infrastructure expansion issues are a potential concern for any new facility that is not accessible from existing roadways. The north shield has not been thoroughly tested for seeing conditions, and a future site for facility development in this area would be contingent on positive findings from seeing analysis.

The proposed site for a new conventional optical/IR telescope is shown in Figure IX-16 and a perspective view is shown in Figure IX-20. The selection of this new site within the Astronomy Precinct generally satisfies the specific siting criteria, including:

1. Minimal impact on existing facilities. A facility proposed at a location to the north of the summit ridge will not cause obscuration for any existing telescopes on the mountain.

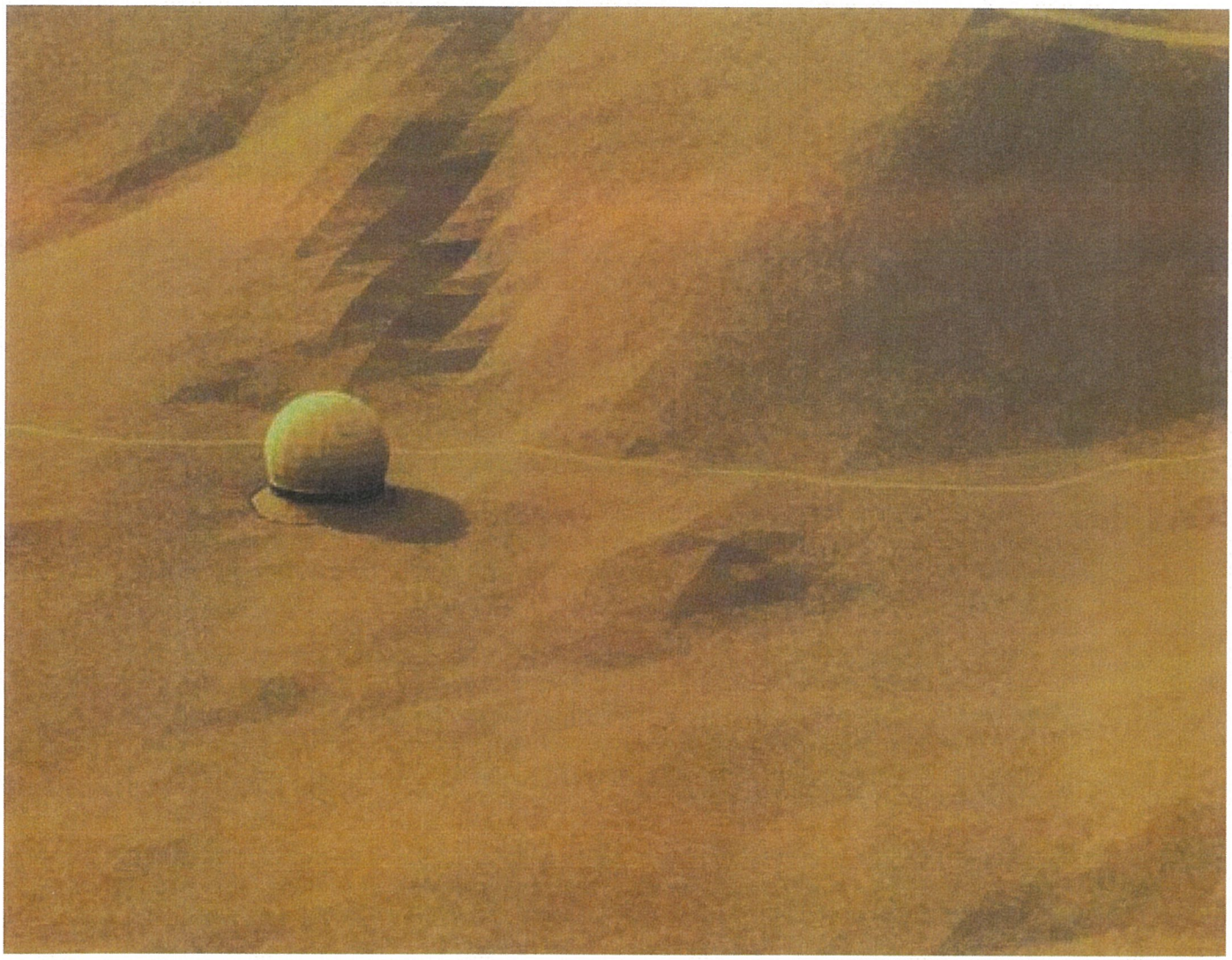
2. Minimum impact of Wēkiu bug habitat. The area to the north slope is outside of the known Wēkiu bug habitat with no pu'u or cinder cone surface geology.

3. Avoidance of archaeological sites. There are no existing archaeological features in the north slope portion of the Astronomy Precinct. The new facility will be set back at least 200 feet from the clustered group of shrines found outside the Precinct boundary further to the north (toward Honoka'a and Waimea). This setback distance is 10 times the minimum setback distance required by the Hawai'i Island Burial Council for development near existing burials.

4. Minimum visual impact from significant cultural areas. Telescope sites on the north slope would be visible from archaeological sites when looking toward the summit, but would not obstruct the visual connections between the major pu'u and these shrine complexes. By locating a new conventional optical/IR telescope site off the summit cinder cones, this will mitigate further diminishment of the integrity of the summit ridge as an historic property.

5. Avoid or minimize views from Waimea, Honoka'a or Hilo. This location is not a prominent site such as the ridges or pu'u. The existing topography of the north slope shields views of new facilities from Hilo. A new telescope at this location would be visible from the Waimea and Honoka'a communities.

6. Close to roads and existing infrastructure. The proposed site for the conventional telescope was selected near to the existing roadways to minimize the amount of disturbance to the natural terrain. Utilities and communications service to the new site will be extended along the existing roadway routes to minimize disturbance.



Proposed Conventional Optical/Infrared Telescopes

The proposed site for a conventional optical/IR telescope satisfies the selection criteria. A perspective view of the new conventional optical/IR telescope on the north slope is shown in Figure IX-20. In order for visual impact to be minimized, the enclosure for this new telescope should be colored to match the surrounding lava/ash terrain. Further, if a new observatory is proposing to develop a mirror with an aperture of greater than 10 m., a partial buried strategy must be applied to diminish the visual impact of these facilities. These requirements are specified in the proposed Design Guidelines.

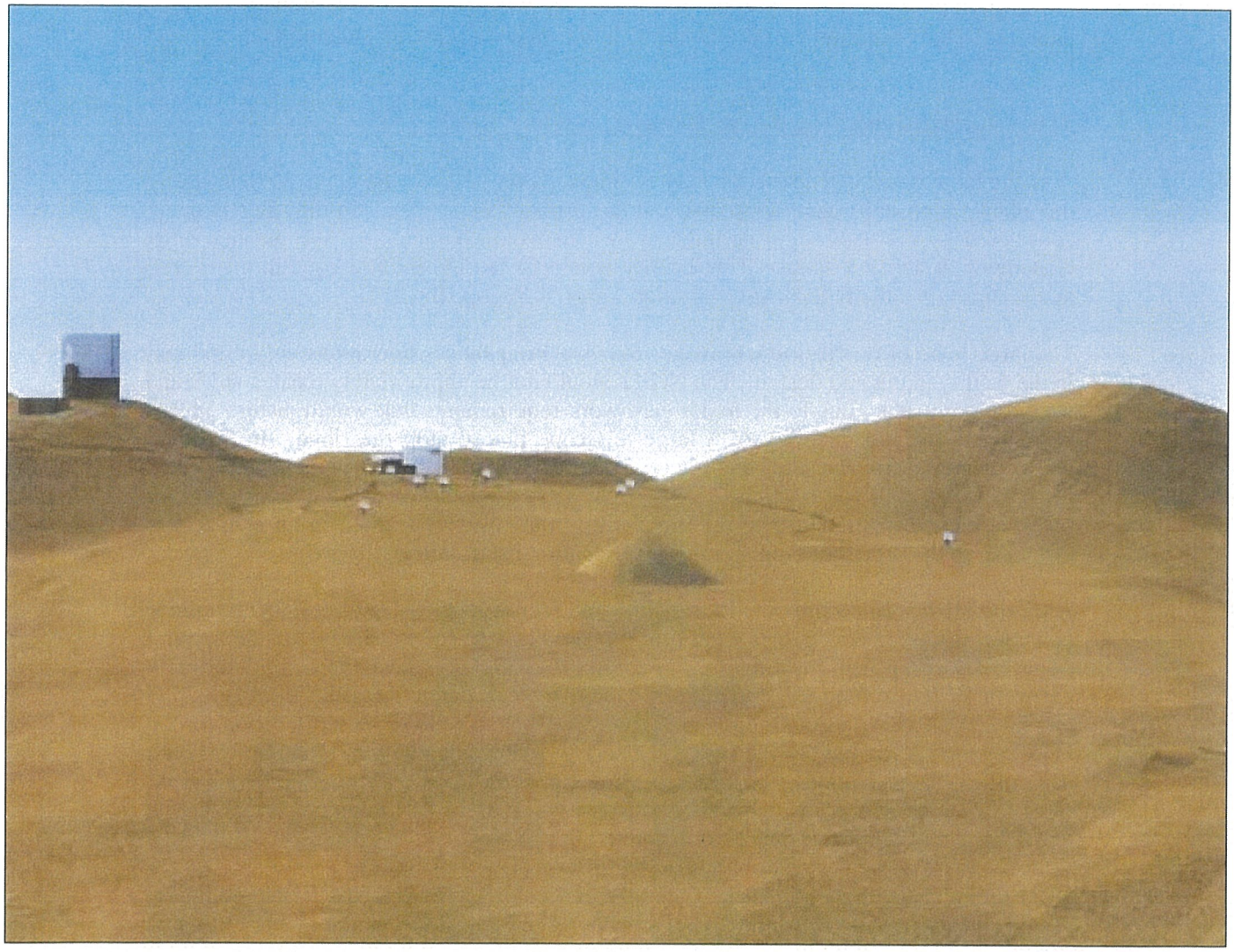
Type IV. Next Generation Large Telescope Site

A single large optical/IR telescope may be proposed for Mauna Kea in the 20-year life of this plan. A ground-based telescope with a mirror of 25 to 50 m. in diameter is being considered by the astronomy community, which would complement the planned Next Generation Space Telescope. This facility would be the largest telescope in the world, and is currently called the Next Generation Large Telescope (NGLT).

The large scale of this instrument makes the visual impact considerations very important in the facility siting and design. The NGLT would not be appropriately located at Mauna Kea's summit ridge, due to the major earthwork requirements that would disturb Wēkiu bug habitat and the visibility of a large telescope placed atop the ridge. In addition, telescope engineers have indicated that wind forces acting on the structure are expected to be severe and problematic. To minimize potential obscuration of existing observatories, the potential site for this facility must also be located in an area that is distant from the prominent topography at the summit ridge and nearby *pu'u*.

A location that would minimize its visibility and reduce wind shear forces, and minimize potential obscuration impacts, would be on the slope to the northwest of the summit ridge. The proposed location of the telescope will take advantage of a northerly extension of the summit ridge to entirely block views of the new facility from Hilo, and partially block views from Honoka'a. Figure IX-16 shows the proposed location for the NGLT, which is located between the SMA service roadway and a jeep road that was built decades ago for preliminary testing of viewing conditions to the northwest of the summit ridge. The presence of the existing roadways will help minimize potential site disturbance for the infrastructure extension to this site.

Strict design guidelines will dictate the size and color of the NGLT. The preliminary design concept proposed for the NGLT employs a unique sliding dome mirror enclosure with a sub-grade foundation, as shown in Figure IX-21. The lower half of this observatory will be built below grade to minimize the apparent height and mass of the facility. The facility shown in the concept has a 30-m. mirror, with a dome shaped and colored to simulate a small *pu'u* to blend well with the surrounding landscape.



Proposed Next Generation Large Telescope (NGLT)

The siting criteria for locating proposed new facilities were applied in selecting the site for the NGLT, discussed as follows:

1. Minimal impact on existing facilities. The observation function of the existing telescopes on the mountain would not be affected by new facilities located to the north or northwest of the summit ridge. The proposed location of the NGLT in the center of the SMA expansion area could potentially obscure some antennas in the SMA expansion. These potential obscuration effects can be minimized or eliminated by cooperative planning for these two facilities.

2. Minimum impact of Wēkiu bug habitat. The proposed site is outside of the Wēkiu bug habitat.

3. Avoidance of archaeological sites. The closest archaeological feature to the proposed NGLT site is a shrine located approximately 1,200 ft. to the east. For reference, this distance is 60 times the minimum setback distance required by the Hawai'i Island Burial Council for development proposed near existing burials.

4. Minimum visual impact from significant cultural areas. The siting of the NGLT respects views from the pu'u and archaeological sites. The NGLT is located to the northwest of the summit ridge, which does not interference with the visual connections between the major pu'u and the shrine complexes.

5. Avoid or minimize views from Waimea, Honoka'a or Hilo. The existing topography shield views of the NGLT from Hilo, however, the facility will be partially visible from Waimea and Honoka'a. The proposed design guidelines for the NGLT will minimize the visual impact of the facility, as discussed previously.

6. Close to roads and existing infrastructure. The NGLT site is close to the existing SMA service roadway, which will minimize the amount of disturbance to the natural terrain. Utilities and communications service to the NGLT site will be extended along the existing roadway routes to minimize disturbance.

To mitigate the visual impact of the telescope, requirements will be imposed to color the telescope enclosure to blend into the surrounding site. The technology for coloring telescope enclosures has yet to be applied in practice, however, this technology is presently being considered by telescope engineers. This design measure will serve to significantly diminish the visual impact of the telescope from both on-mountain and off-mountain locations. Coloring of the telescope enclosure and other strategies are included in the Design Guidelines.

Type V. Optical/IR Interferometer Array (General Area Only)

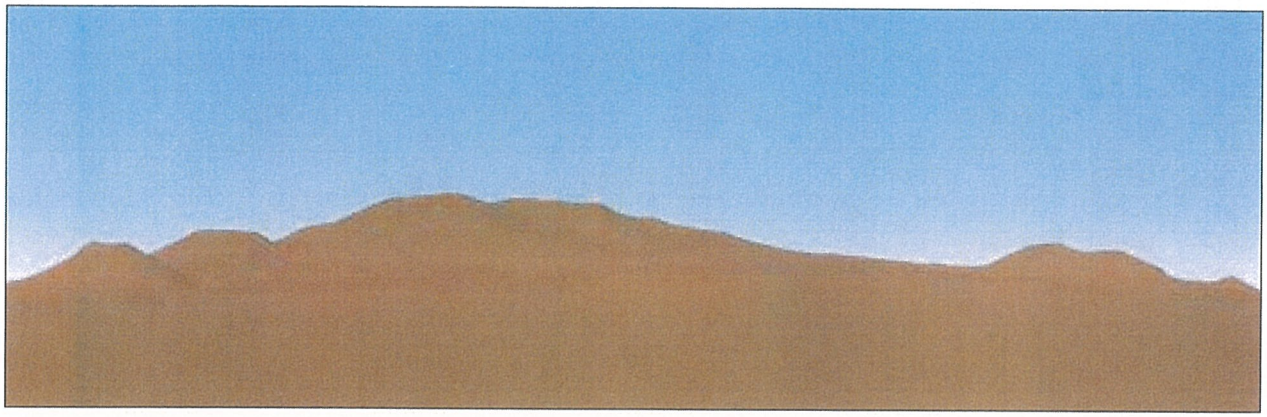
Development of an Optical/IR interferometry array requires a large and relatively level area of up to 1.0 km. in diameter. Within Mauna Kea's Astronomy Precinct, there is a plateau area to the northwest of the summit ridge that is approximately 0.8 km in diameter. At this location, this type of facility could extend approximately 0.8 km in diameter, with multiple telescope elements collecting light, arranged in a roughly circular array. The number of collecting elements cannot be accurately quantified at present due to the current state of the technology for optical/IR interferometry. The light collected by these devices would be combined at a central location to resolve the image of the target object.

At present, the technology has yet to be developed which would allow for the light to be combined from an optical interferometer of this scale, without the construction of large light combining structures and miles of vacuum tube being installed. These types of support facilities are deemed inappropriate for Mauna Kea. Advances in the use of fiber optics and light processing technology for this purpose are required before a facility such as this could be appropriately built at Mauna Kea. These advances are currently being studied intensively by telescope development engineers.

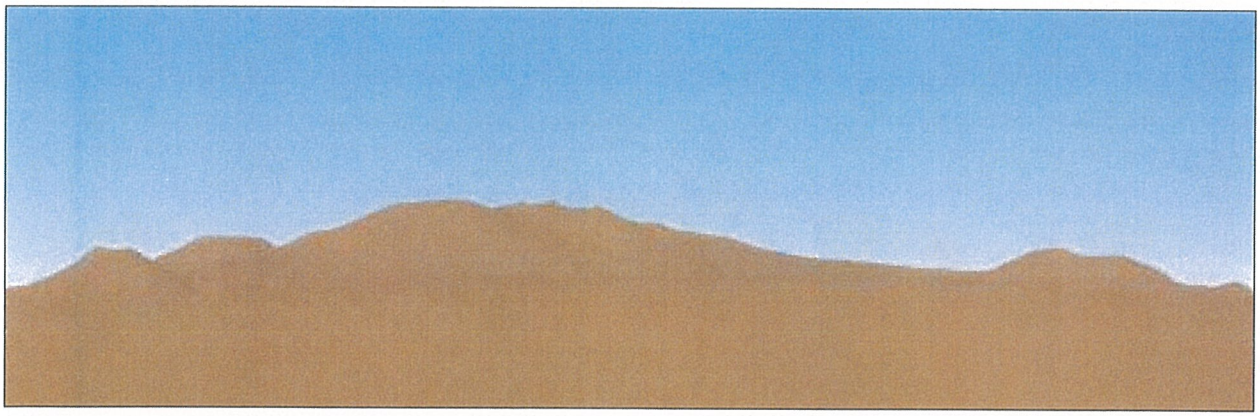
In anticipation of the advances of the light combining technology, and to provide direction for telescope designers, the physical plan guides the possible placement of this instrument within the northwestern quadrant of the Astronomy Precinct. There is no Telescope Siting Area defined to accommodate this possible instrument. For general planning purposes, the Master Plan presents a general area to provide an opportunity for possible further study of the instrument at some point in the next 20 years. A lengthy and thorough process of a General Amendment to the Master Plan would be required to advance this project to the facility siting, design and permitting phase, including a full EIS and CDUA.

A proposed design strategy for minimizing the visual impact of the interferometer includes partial burial of the interferometer elements and creating visually-minimized enclosures. A clamshell enclosure with "pop-up" collecting device should be considered. Along with these design measures, the enclosures should be colored to match the surrounding landscape. Together with the low profile of the instruments, these measures would essentially shield and camouflage the interferometer from view.

Due to the unspecified project characteristics at this time, only a general area for the optical/IR interferometer is proposed within this master plan. If an optical/IR interferometer proposal is advanced in the next 20 years, the project will require a major master plan amendment, involving the full range of planning analysis, visual impact analysis, and preparation of an environmental impact statement (EIS), and final review by the UH Board of Regents.

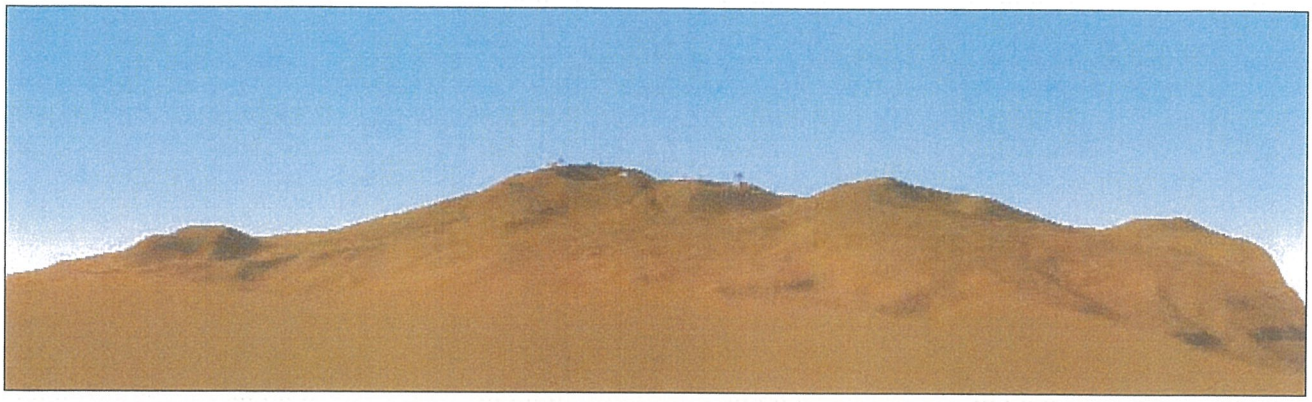


Existing View from Hilo

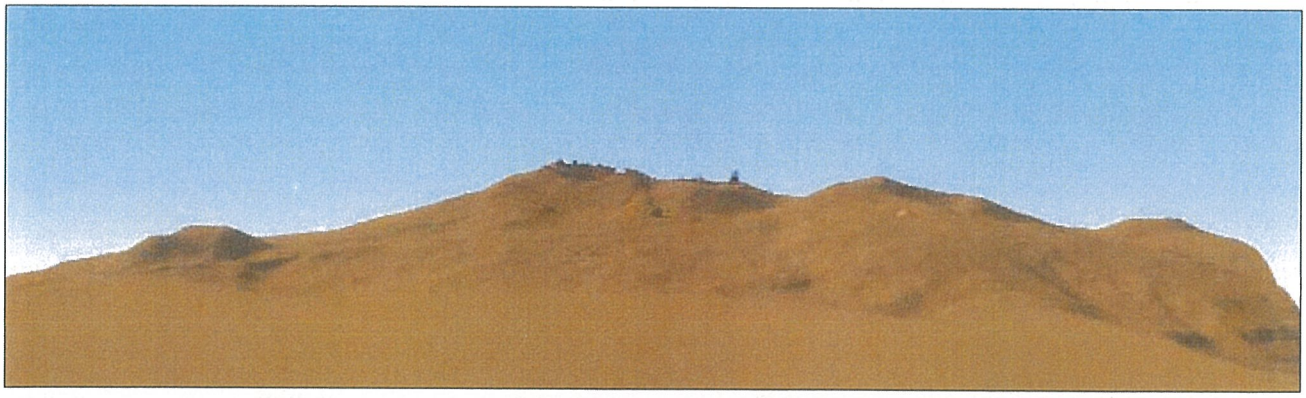


Future View from Hilo

Views from Hilo

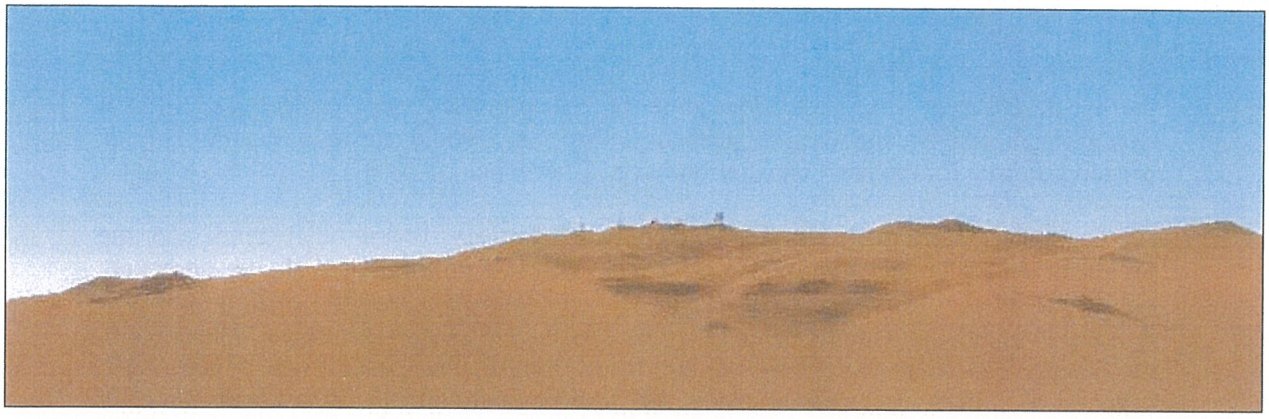


Existing View from Honoka'a

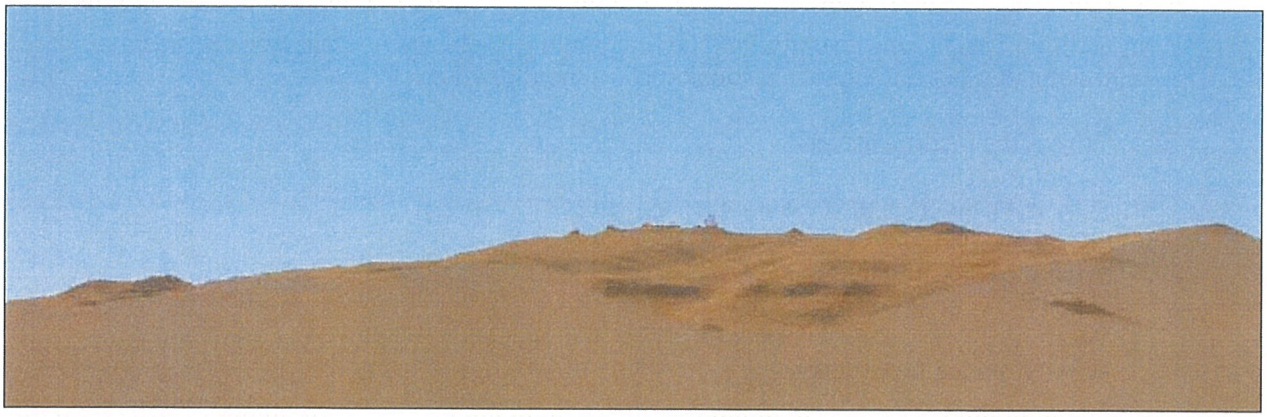


Future View from Honoka'a

Views from Honoka'a



Existing View from Waimea



Future View from Waimea

Views from Waimea

Planning Guide Summary and Approval Process for Astronomy Precinct

A list of the existing and proposed future observatories for which there are identified siting areas in this master plan is shown on Table IX-1 (page IX-45). The likelihood of all of the identified facility upgrades and proposed new facilities being developed is extremely remote, and the expected scope of development is 50 to 75 percent of the observatories listed. The timing for future development is undefined at present, except for the Keck Outriggers project. For some of the proposed new projects, significant technological advancements are needed before they could move forward. This is particularly true for the Next Generation Large Telescope.

As described in Chapter XI, the University of Hawai'i Board of Regents and the President retain project approval and design review authority over all developments within the Science Reserve. To assist the University in its evaluation of proposed new development, all applications will be reviewed by the Office of Mauna Kea Management, the Mauna Kea Management Board, and the Kahu Kūpuna Council (see Figure XI-2, page XI-8). In making any decisions on project approval, the Board will carefully consider the advice received from the above three groups.

Each of the redeveloped or proposed new facilities, including any non-astronomy facilities, will undergo individual project reviews, which include an environmental analysis pursuant to Chapter 343 Hawai'i Revised Statutes and a comprehensive analysis of the potential cultural impact. The Kahu Kūpuna Council will assist in establishing the criteria for these analyses. It is expected that some of the criteria will be specified by State requirements.

In addition, each new facility will be required to present a detailed justification addressing, but not limited to, questions such as the following:

(1) Why is the facility needed?

(2) Why is Mauna Kea the best site for the facility?

(3) What other location options are available?

(4) What are the expected benefits: research and education, employment and economic activity, potential revenues?

(5) What is the expected facility lifetime and term of the sublease agreement?

Table IX-1

EXISTING AND PROPOSED OBSERVATORIES AT MAUNA KEA SCIENCE RESERVE

Observatory (Aperture Diameter)	Proposed Master Plan Action
University of Hawaii (0.6 m.)	Redevelop: 2-3 m.
University of Hawaii (2.2 m.)	Redevelop: 4-12+ m.*
Canada-France-Hawaii Telescope (3.6 m.)	Redevelop: 4-12+ m.*
United Kingdom Infrared Telescope (3.8 m.)	Redevelop: 4-12+ m.*
NASA Infrared Telescope Facility (3.0 m.)	Redevelop: 4-12+ m.*
Caltech Submillimeter Observatory (CSO) (10 m.)	Remain As-Is
James Clark Maxwell Telescope (JCMT) (15 m.)	Remain As-Is
Very Long Baseline Array (VLBA) (25 m.)	Remain As-Is
W. M. Keck Observatory (Keck I & II) (10 m.)	Add 4-6 1.8 m. Outrigger Telescopes
Gemini Telescope (8 m.)	Remain As-Is
Subaru Telescope (8 m.)	Remain As-Is
Submillimeter Array (SMA) (12 6-m. Antennas)	Add 12 Antennas
New: University of Hawaii – Hilo	New Site, 1 m. (Instructional)
New: Conventional Optical/IR	New Site, 4-12+ m.*
New: Next Generation Large Telescope (NGLT)	New Site, 25+ m.

Note: All new and redeveloped facilities require individual project review and approval. The NGLT will require the development of new technology.

* It is expected there will be a range of telescope sizes proposed in this group. Exterior dimensions of those on the ridge will be limited by Design Guidelines.

RECREATION PLAN COMPONENTS

The final integration of the Master Plan involves the recreational resource components in the Science Reserve. This plan provides direction for future recreational uses within the Science Reserve, including any potential facilities to support recreation on Mauna Kea. Recreation components, such as hiking, hunting, skiing, snow play and tourism, are addressed in an integrated approach overlaid upon the integrated plan of natural and cultural resources and education and research resources. The overall objectives for recreational resources are listed below.

Overall Objectives

1. Expand understanding of recreational uses and potentials of the Science Reserve.

2. Retain and enhance recreational opportunities within the Science Reserve, while protecting natural, cultural resources, and cultural practices.

3. Define areas, criteria and support facilities for recreational uses, sight seeing and commercial tours, as applicable, to allow for sustainable, integrated planning and management.

Recreational Resources Plan. The traditional uses for recreation on Mauna Kea, and the pattern of these uses, determines the form of the recreational plan component. Access to recreational resources will be enhanced and managed to ensure the protection of the natural, cultural, education and research resources. Hiking trails, ski areas and scenic viewpoints will be delineated within the Science Reserve to allow people to witness the unique resource areas while ensuring their protection. As part of the plan, the following facilities are planned:

- Recreational support facility in the summit region to support skiing, snow play, visitor tours and scenic resource enjoyment;
- A parking area that is primarily planned to serve cultural resource interests, located along the access road at the 13,000 ft. elevation; and
- Cabin camping by organized groups, using the planned conversion of the construction cabins built by the Subaru observatory at Hale Pōhaku.

Further details of the Recreational Plan elements are discussed in the following section.

Physical Plan: Expanded Understanding of Recreational Resource

While there are physical components to the recreational plan, most recreational issues are addressed in the management plan. There are modest facilities needs for recreational support, and support facilities to serve the cultural resource component overlap in certain cases.

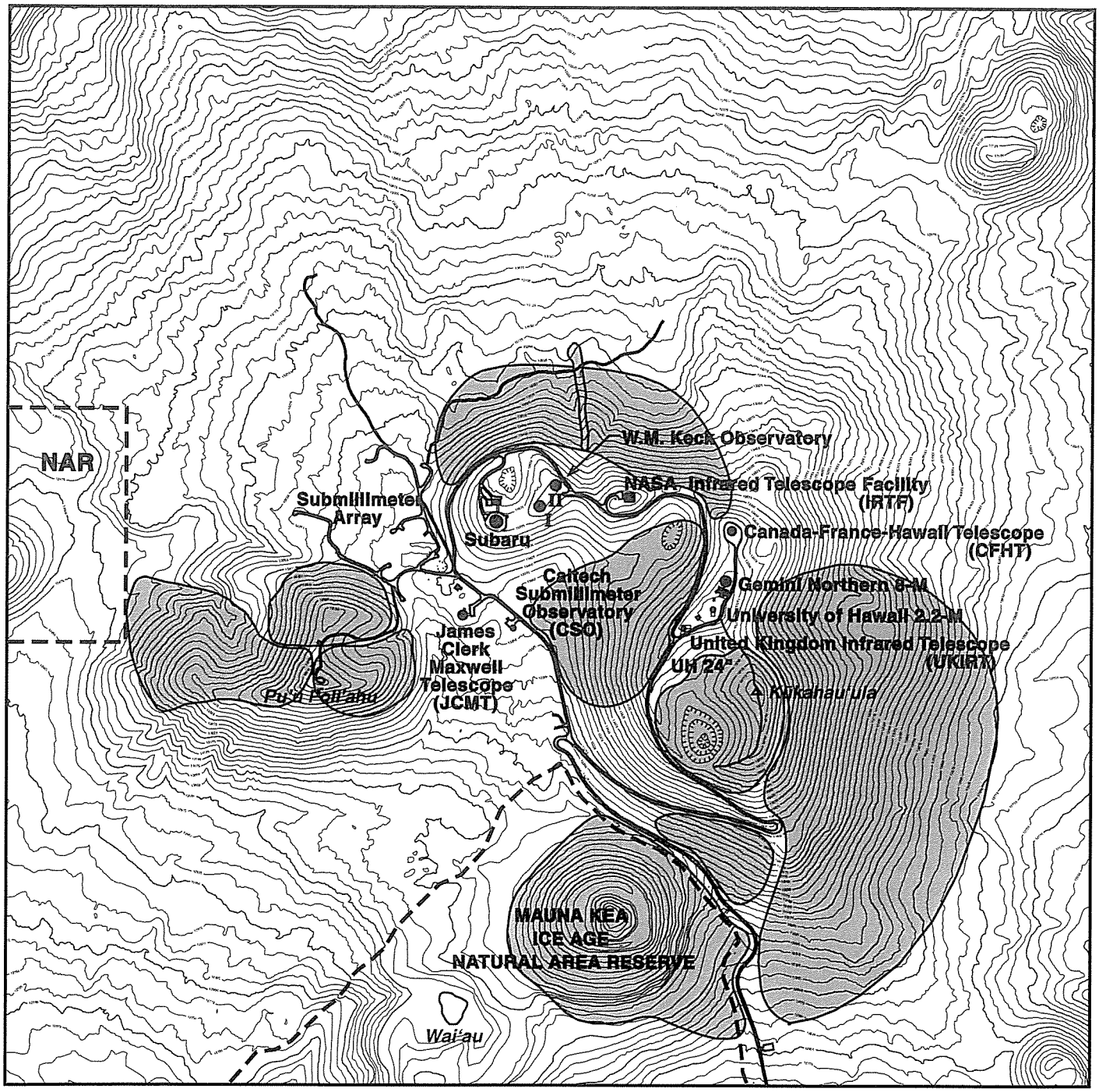
Skiing and Snow Play. Skiing and snow play activities are very popular recreational uses of Mauna Kea during periods of winter snowfall. Figure IX-25 shows the extent of popular ski runs and snow play areas in the summit area. It is also proposed that skiing and snow play use be restricted from the significant cultural landform of Pu'u Poli'ahu. Snow play activities are centered around the Poi Bowl area. Snow play will also be restricted to areas without archaeological sites and cultural preserve areas. Parking and bathroom facilities are existing needs to support skiing and snow play activities.

A recreational support facility is planned within the summit region to support skiing, snow play, visitor tours and scenic resource enjoyment. The support facility is planned to be located at the base of "Poi Bowl" along the summit access road in Millimeter Valley, at the center of skiing and snow play activity at the summit during winter months. The facility would include a shelter, rest rooms, emergency equipment storage, an emergency telephone, and possibly a small office space for the rangers. The design of the facility is envisioned as a building built into the surrounding landscape such that its presence will not detract from its natural setting. It is not to be a "ski lodge".

Individual Visitors and Tours/ Scenic Vista Out-Look Locations. The master plan defines areas for specific visitor stopping points in the Science Reserve and at the summit. Scenic lookout points will be organized at the summit at two locations where the observatories are willing to accommodate limited public access. Currently the Keck observatory sites allow such use, with the Keck Observatory providing a Visitor's Gallery including restrooms. Very limited parking areas are present to serve the visitor areas, and visitors will generally be directed to use the restroom facilities planned for the Poi Bowl area.

Trails. In the rugged terrain in the upper slopes of Mauna Kea, trails to Wai'au and the summit are evident on historic maps and on the ground today. Past ranching activities were responsible for creating the more defined trails. Interviews of informants with historical knowledge of Mauna Kea identified the routes of historical trails (Figure V-4).

The plan is to preserve the existing historical trails to Wai'au and the summit. To protect the resources of the Science Reserve, formal public hiking routes within the Science Reserve will be mapped in the future, and trail improvements will be planned as needed for safety. A recreational support facility, including a parking lot and restrooms, is planned for the Millimeter Valley area and will be available to hikers and other users.



Source: 1983 Mauna Kea Science Reserve Complex Development Plan, Dr. Jerry Johnson, 1998

Ski Areas

25' Contour Intervals

Natural Area Reserve

0' 750' 1500' 3000'

NORTH

Existing Ski Areas

Another support facility is a parking area that is primarily planned to serve cultural resource interests, located along the access road at the 13,000 ft. elevation. This location will provide access to existing trails leading to Wai'au and the adze quarry. These uses are directed to defined areas of the Science Reserve to protect the sensitive natural and cultural resource components. Development of this support facility will be subject to approval by the DLNR.

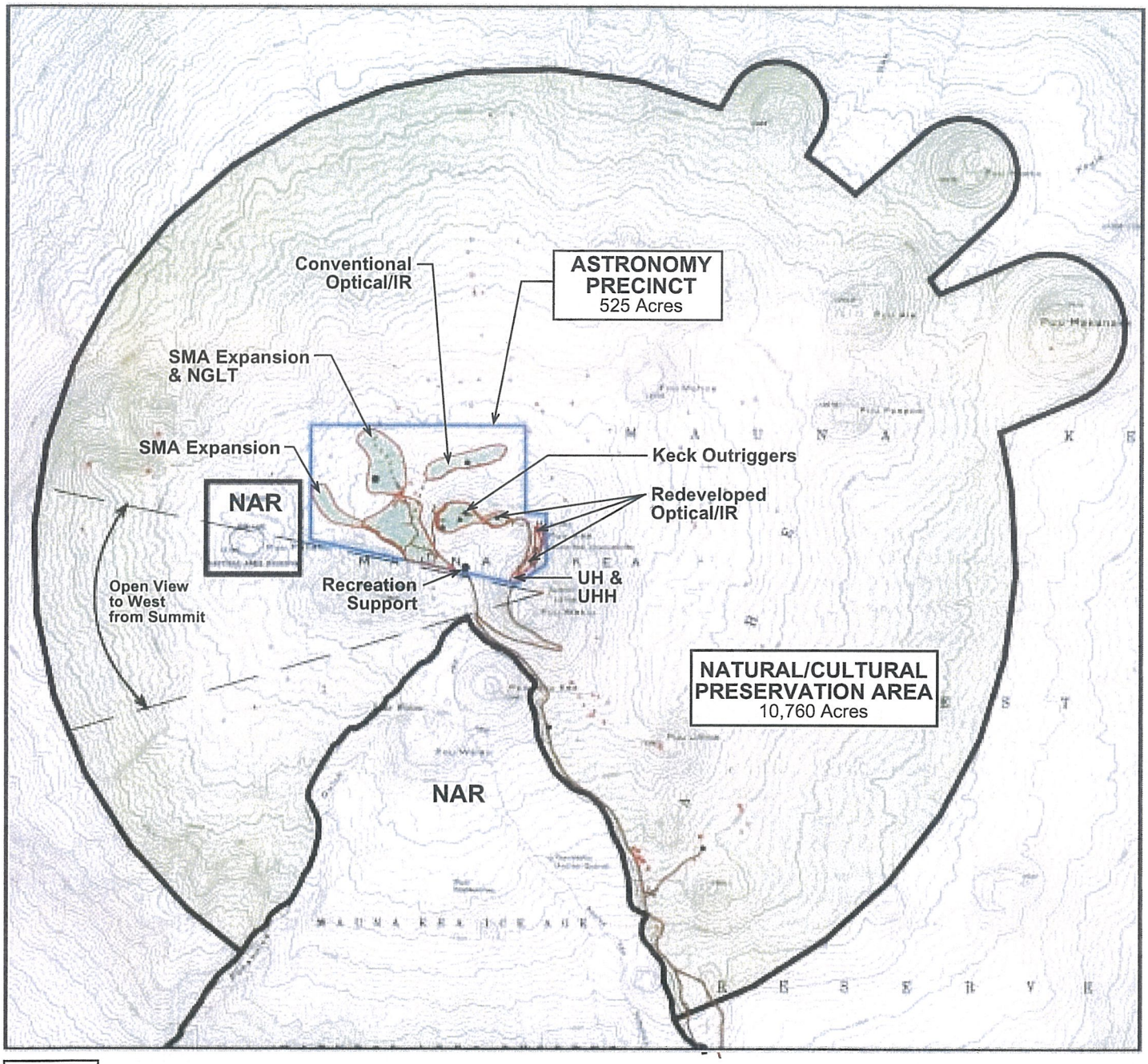
Camping. The public will also benefit from the planned conversion of the construction cabins built by the Subaru observatory at Hale Pōhaku. These will be turned over after construction operations cease (2001) and become available for public group stays.

Hunting. Hunting activity in the Science Reserve generally only occurs in the lower and mid-elevations of Mauna Kea. Hunting areas are shown in Figure VII-1. Access for hunters is available through Hale Pōhaku and Pu'u La'au. The Master Plan places no new restrictions on the future use of the Science Reserve for hunting.

Recreational Physical Plan. The recreational use elements of the Science Reserve are depicted as broad use areas for skiing, snow play, hiking and hunting. Specific landforms, such as Pu'u Poli'ahu have been designated as off-limits for future recreational use to respect the cultural significance of this *pu'u*. The plan includes informational signage for visitors such that a well-planned tour can be conducted without random stopping points that can result in adverse effects to important natural and cultural resources.

Overall Physical Planning Guide for Summit

An overall plan of the summit region is shown in Figure IX-26. The physical plan identifies all of the locations for existing and proposed astronomy facilities in the Astronomy Precinct. Also shown in the plan is the location of the recreational support building within the Precinct. This plan depicts a composite of all resource components into one integrated plan. Natural and cultural resources elements are preserved throughout the Science Reserve, with particular focus on the 10,760-acre Natural and Cultural Preservation Area surrounding the proposed Astronomy Precinct. Proposed facilities to support education/research and recreational elements are limited within the approximately 525-acre Astronomy Precinct.


Conventional
Optical/IR
ASTRONOMY
PRECINCT
525 Acres
SMA Expansion
& NGLT
SMA Expansion
Keck Outriggers
NAR
Redeveloped
Optical/IR
Open View
to West
from Summit
Recreation
Support
UH &
UHH
NATURAL/CULTURAL
PRESERVATION AREA
10,760 Acres
NAR
40' Contour Intervals
0'
2000'
4000'
8000'
NORTH

PLAN FOR HALE PŌHAKU MID-ELEVATION FACILITIES

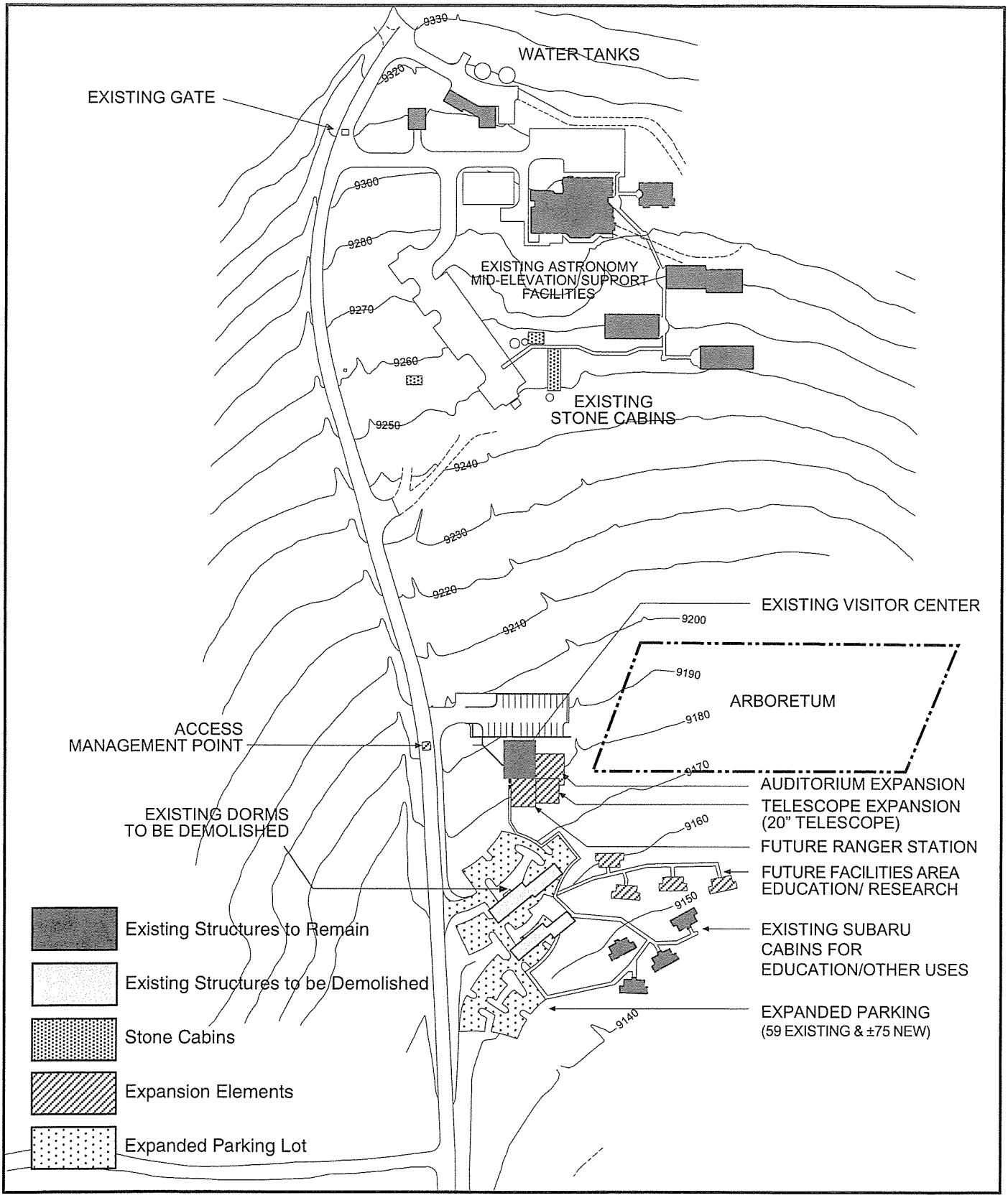
The mid-elevation facilities at Hale Pōhaku have typically been associated with support of astronomers, dating back to times when all facilities were operated by on-mountain astronomers and technicians. With today's technology and the fiber optic communications system, many of the studies occurring at these observatories can be operated remotely either from Hale Pōhaku, off-mountain Hawai'i locations (Waimea, Hilo), or via the Internet. Hale Pōhaku's role in providing public information and education about astronomy on Mauna Kea will be augmented by these base facilities and a planned planetarium in Hilo. Refer to the following section for additional detail regarding the off-mountain base facilities.

Even with the change in operating procedures, portions of the Hale Pōhaku facilities are being planned to accommodate increased non-astronomy use in the next 20 years. There are three components to the Hale Pōhaku facilities that are addressed in the plan, including: 1) Astronomy mid-elevation facilities, 2) Construction camp facilities, and 3) the Visitor Information Station facilities. Existing facilities at Hale Pōhaku, and uses planned at these locations, are described below and shown in Figure IX-27.

1. Astronomy Mid-Elevation Facilities. Due to the increased capability for off-mountain viewing, use of the existing astronomy mid-elevation facilities has been declining, and this trend is generally anticipated to continue or stabilize near current levels. As the total number of observatories on the summit will be increasing, overnight stays at the mid-elevation facility will generally decline on a per facility basis. This will result in a total number of overnight stays that is anticipated to be comparable to the present levels, therefore there will be no need for expansion.

2. Construction Camp Facilities. The older camp facilities are to be removed. The Subaru construction cabins will become fully available to the State in 2002. These cabins are proposed to be used for additional purposes including education, research and recreation, including:
   - Increased use by University of Hawai'i at Hilo, other college/university-level academic programs relating to geology, alpine and mountain forest ecology, astronomy and Hawaiian culture, as well as groups from schools and organizations.
   - Periodic temporary lodging for observatory construction crews for future projects.

3. Visitor Information Station Facilities. The visitor center facilities will require further expansion, which will complement the planned programs at UH-Hilo. A visitor information center will be included in the facility. Other possible uses could include natural and cultural resources interpretive center, and the ranger station offices and communications center. The new controlled access point on the summit road will occur at the Visitor Information Station, replacing the present (open) gate located at the astronomy mid-elevation facility. Current plans for the Visitor Information Station expansion include an auditorium addition and new observatory. The anticipated users of the Visitor Information Station are described below in several categories.


WATER TANKS
EXISTING GATE
EXISTING ASTRONOMY MID-ELEVATION/SUPPORT FACILITIES
EXISTING STONE CABINS
EXISTING VISITOR CENTER
ARBORETUM
ACCESS MANAGEMENT POINT
AUDITORIUM EXPANSION
TELESCOPE EXPANSION (20" TELESCOPE)
FUTURE RANGER STATION
FUTURE FACILITIES AREA EDUCATION/ RESEARCH
EXISTING SUBARU CABINS FOR EDUCATION/OTHER USES
EXPANDED PARKING (59 EXISTING & ±75 NEW)
EXISTING DORMS TO BE DEMOLISHED
Existing Structures to Remain
Existing Structures to be Demolished
Stone Cabins
Expansion Elements
Expanded Parking Lot
9330
9320
9300
9290
9270
9260
9250
9240
9230
9220
9210
9200
9190
9180
9170
9160
9150
9140

- Visitors attracted or directed by the planetarium program at UH-Hilo's University Park. People visiting the planetarium will learn about the Hale Pōhaku facilities, and some will visit the Mid-Elevation facilities for a first-hand experience of the mountain's cultural and educational resources.
- Private tour groups and individual travelers are also expected to travel to Hale Pōhaku in greater numbers. With the improvement of the Visitor Information Station, its reputation will grow and people's interest in witnessing the facility and experiencing its programs about the mountain will expand. A 20-inch telescope will be installed at the VIS so the visitors and amateur astronomers can observe the sky in Mauna Kea's superior conditions. Other public astronomy facilities may also be developed in the future. All improvements at Hale Pōhaku are subject to design review.
- Non-astronomy research groups (e.g. geology, botanical, faunal, cultural, etc.) will also increase over time. These types of groups will travel to the Visitor Information Station to experience exhibits and programs highlighting the unique natural and cultural resources of the mountain.
- Recreational use by naturalists and cultural groups will expand. Individuals and organizations are anticipated to utilize the Visitor Information Station for their own recreational enjoyment or for organized functions.
- Primary-level educators will utilize the Visitor Station for school field visits and educational programs (e.g. geology, botanical, faunal, cultural, etc.)

The anticipated increases in use will create the need for additional parking area at the Hale Pōhaku Visitor Information Station. The number of parking spaces is currently planned to increase by 75 spaces to a total of approximately 150 spaces. More parking may be needed at the Visitor Center in the future.

The number of travelers to Hale Pōhaku utilizing Saddle Road and the Mauna Kea Access Road is expected to increase in the future. Future improvements planned for Saddle Road by Hawai'i County will also allow for better access to Hale Pōhaku. Mauna Kea Access Road is not currently planned for improvements. However, future use levels at the Visitor Information Station may warrant additional work such as increased signage, new pavement and striping, and minor widening of pavement for paved shoulders.

OFF-MOUNTAIN BASE FACILITIES

It is difficult to conduct research investigations for prolonged periods at the high altitude locations of the Mauna Kea summit or Hale Pōhaku. In addition, it is difficult to access the observatories in harsh winter weather periods. Several observatories have found it more effective to conduct their studies from off-mountain base facilities. With the installation of fiber optic communications to the observatories on Mauna Kea, they now have the capability to be operated remotely. Off-mountain base facilities for these observatories have been established in Waimea (CFHT and Keck) and University Park in

Hilo (UKIRT, JCMT, CSO, Subaru, Gemini, and IfA). The trend toward providing off-mountain base facilities is expected to continue.

Some facilities, such as the Submillimeter Array (SMA), can be operated remotely via the Internet from its home base in Cambridge, Massachusetts. SMA also has offices in Hilo from which it conducts its current operations in Hawai'i. Future telescopes constructed at Mauna Kea will be encouraged to develop their base facilities in Hawai'i to the greatest extent practical.

Future observatory construction at Mauna Kea may require additional base facilities to be constructed in either Waimea or Hilo. The most recent base support facilities have been developed at University Park on the campus of UH-Hilo. In addition, UH-Hilo proposes to locate the Mauna Kea Astronomy Education Center, an educational and interpretive facility designed to broaden, public understanding of the Universe, at University Park, as noted in Appendix B.

INFRASTRUCTURE REQUIREMENTS

Infrastructure elements serving the Science Reserve will require periodic updating and expansion to serve the various users of the mountain in the next 20 years. Education and research facilities within the Astronomy Precinct will have facility requirements for updating and expansion of roadways, communications system, and electrical power supply. Infrastructure maintenance will be an ongoing requirement, which is addressed in the management plan.

Roadways. Roadway expansion will be minimized through the development siting criteria, which guides future facilities to be developed near the existing roadways. The existing unimproved roadways serving the expansion sites within the Astronomy Precinct will require additional improvement. Although there are narrow road alignments present, these roads will require modest widening and grading to make them passable for new facilities operations located beyond the existing astronomy areas at Millimeter Valley and the summit ridge. The Master Plan recommends paving of the remainder of the access road from Hale Pōhaku and the remainder of the summit spur road which runs from the SMA building past the Subaru Telescope to the W.M. Keck Observatory. Paving will reduce the amount of dust generated by vehicles, thus improving conditions for astronomy observations and for Wēkiu habitat.

Communications and Power Supply. The fiber optic communications system and the electrical power system will be expanded to serve new facilities sites to the north and northwest. The main power supply to the mountain is adequate to serve the additional facilities anticipated under this plan. To minimize the visual impact of new utility pull boxes to be located along the new underground conduit routes, colored concrete will be used to match the surrounding ground surface.

Water Supply. There is no water supply extending to the summit of Mauna Kea, and future water supply to the summit will continue to follow current procedures. Water will continue to be provided from two 40,000-gallon water tanks located at Hale Pōhaku. Currently, 25,000 gallons of water are trucked to the mid-level facility from Hilo each week. Each of the observatories will continue to be supplied with potable water that is transported to the summit by tanker trucks from Hilo. About 15,000 gallons of water is presently trucked to the summit each week, and each facility has its own water storage tank. The supply rate will increase to serve new facilities that are planned for the summit. Changes to technology allowing remote (off-mountain) viewing access could reduce the number of workers and scientist actually present at new facilities, and a corresponding lower water use rate as compared to existing facilities.

Wastewater Management. There is no plan for construction of a sewer collection system to serve the summit area. Wastewater generated at the observatories will continue to be managed by each facility through individual wastewater disposal systems (cesspools and septic tank/leaching field systems). Due to the small number of workers and visitors utilizing these facilities on a daily basis, the volume of water use and wastewater generation is small, approximating domestic rates. Changes to technology allowing remote (off-mountain) viewing access could reduce the number of workers and scientist actually present at new facilities, and a corresponding lower water use and wastewater generation rates.

Drainage. Erosion due to storm water runoff will be controlled on all new roadways, such that there will be no adverse affects to the surrounding landscape. There are six culverts within the 4.5 miles of roadway from Hale Pōhaku to the summit. Culverts will be installed as needed along the extension of the access roadway system to the north to minimize erosion

Summary of Physical Planning Guide for the Science Reserve and Hale Pōhaku

The overall physical planning guide for the Science Reserve depicts a composite of all resource components into one integrated plan. Natural and cultural resources elements are preserved throughout the Science Reserve, with particular focus on the 10,760-acre Natural and Cultural Preservation Area surrounding the proposed Astronomy Precinct. Proposed facilities to support education/research and recreational elements are limited within the approximately 525-acre Astronomy Precinct, except for improvements to facilities at the Hale Pōhaku Visitor Center.

This updated physical plan, in conjunction with the updated Management Plan (discussed in the following section), creates a living planning and management document that has been developed in collaboration with the University, Mauna Kea Advisory Committee, native Hawaiian interests, and other stakeholders and interested community members.