4 ENVIRONMENTAL IMPACTS

This Chapter presents information on the potential environmental impacts of the Proposed Action and reasonable alternatives. The environmental impacts are examined for (1) on-site construction and installation, and (2) operation of the Outrigger Telescopes. In addition, this chapter addresses the cumulative impacts of past, present, and reasonably foreseeable future activities when combined with the impacts of the Outrigger Telescopes Project.

4.1 POTENTIAL ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

The National Aeronautics and Space Administration's (NASA) Proposed Action is to fund the on-site construction, installation, and operation of four, and possibly up to six, Outrigger Telescopes at the W.M. Keck Observatory site. It is anticipated that the on-site construction and installation of four of the six Outrigger Telescopes, along with on-site construction of the underground structures for Outrigger Telescopes 5 and 6, would begin in 2005 (upon issuance of all State and local permits and approvals), with start of operations anticipated no earlier than 2007. If funding becomes available, NASA intends to complete the installation and operation of Outrigger Telescopes 5 and 6, with on-site construction and installation likely to begin no earlier than 2007.

This section presents information on the potential environmental impacts of the Proposed Action and the No-Action Alternative, discussed in Chapter 2. The environmental impacts are examined for (1) on-site construction and installation, and (2) operation of the Outrigger Telescopes.

Each environmental resource section addresses the region of influence (ROI), that is, is the physical area that bounds the environmental, economic, or cultural feature of interest for the purpose of this analysis. Each subsection defines the ROI for that area, and then discusses the impacts directly related to it. Section 4.1 addresses the impacts directly related to the on-site construction, installation, and operation of the Outrigger Telescopes. Section 4.2 addresses the impacts of the Outrigger Telescopes Project when combined with past, present, and reasonably foreseeable activities.

4.1.1 Cultural Resources

4.1.1.1 ROI for Cultural Resources

Cultural resources include historic properties, cultural values, and traditional cultural practices. The ROI for cultural resources includes the summit and slopes above the Mauna Kea Saddle, from about 1,830 meters (m) (6,000 feet (ft)) above sea level (asl) to the highest summit cone, an area of special importance to Native Hawaiians. This assessment focuses primarily on the area that the Outrigger Telescopes Project would directly impact, the land around the W.M. Keck Observatory where the telescopes would be built and the construction staging areas at the summit south of the W.M. Keck Observatory site and at Hale Pōhaku.

4.1.1.2 Impacts of the Outrigger Telescopes Project on Cultural Resources

Impact Assessment Process. This section identifies the impact assessment process for archaeological and traditional cultural resources. This cultural impact evaluation includes information on the practices and beliefs of Native Hawaiians. Information has been obtained through background research, the Environmental Impact Statement (EIS) scoping process and scoping meetings held in January 2004, town hall meetings held for NASA's earlier Environmental Assessment (EA), and Section 106 consultation meetings, supplemented with existing ethnographic interviews and oral histories (see Section 3.1.2.3)

On-Site Construction and Installation Impacts. Potential impacts of construction and installation of the Outrigger Telescopes on archaeological sites, traditional cultural properties, and traditional cultural practices are addressed for the summit installation site and summit staging areas, and Hale Pōhaku staging area.

Historic Properties. In a letter to the University of Hawaii (UH) dated May 3, 1999, the State Historic Preservation Division (SHPD) stated for the first time that, "…we have come to believe that the cluster of cinder cones which merge and collectively form the summit of Mauna Kea is an historic property and that this single landscape feature probably bore the name Kūkahau'ula. This single landscape feature is now called Pu'u Hau'oki, Pu'u Kea, and Pu'u Wēkiu. Several lines of evidence lead to the conclusion that the cluster of cones is an historic property …Given our conclusion that Pu'u Hau'oki is part of an historic property, we believe the proposed construction of four to six outrigger telescopes on the site of the W.M. Keck Observatory will have an "adverse effect" both on this historic property and on the summit region that we believe is eligible for inclusion in the National Register as an historic district. …We believe, however, that these "adverse effects" can be mitigated if appropriate measures are adopted…" (see Appendix B of this EIS) (SHPD 1999).

SHPD concludes that the summit region is eligible for inclusion on the National Register of Historic Places (NRHP) as an historic district because "it encompasses a sufficient concentration of historic properties (i.e., shrines, burials and culturally significant landscape features) that are historically, culturally, and visually linked within the context of their setting and environment" (SHPD 1999; DLNR 2002). Pu'u Hau'oki is a culturally significant landscape feature within the district. SHPD recommended that the boundaries of the district coincide with the "extent of the glacial moraines and the crest of the relatively pronounced change in slope that creates the impression of a summit plateau surrounding the cinder cones at or near the summit (i.e., generally above the 3,536 to 3,658-m (11,600 to 12,000-ft) contour)" (SHPD 1999).

In response to the May 3, 1999, letter, NASA contacted and solicited comments from Native Hawaiian organizations and other interested parties. NASA used input from the SHPD and the State of Hawai'i Office of Hawaiian Affairs (OHA) to help identify Native Hawaiian organizations that might be interested in providing their input on the proposed project. NASA participated in several meetings hosted by Native Hawaiian organizations, receiving comments at those forums not only from the host organizations, but also from representatives of other Native Hawaiian organizations and individuals.

On the basis of information in the SHPD's letter and comments from Native Hawaiian organizations and individuals, NASA concurred with the SHPD that the cluster of cinder cones of which Pu'u Hau'oki is a component should be considered an historic property and that the summit region of Mauna Kea should be considered an historic district eligible for listing on the NRHP.

NASA concluded that the proposed Outrigger Telescopes Project would have an adverse effect on the cluster of three cinder cones and summit region that are eligible for listing in the NRHP.

NHPA Section 106 Consultation Process. Pursuant to regulations under the National Historic Preservation Act (NHPA), NASA proceeded with the Section 106 process. Initially, NASA formally invited four Native Hawaiian organizations to act as Consulting Parties:

- Hui Mālama I Nā Kūpuna o Hawaiʻi Nei (this organization is referenced in the NHPA)
- Hawaiʻi Island Burial Council
- OHA (also referenced in the NHPA)
- The Royal Order of Kamehameha I.

The Advisory Council on Historic Preservation (ACHP) also agreed, at NASA's invitation, to participate in the Section 106 process. Two more Native Hawaiian organizations later requested and were given Consulting Party status: Ahahui Ku Mauna and Mauna Kea Anaina Hou.

NASA has also consulted with and invited the Office of Mauna Kea Management (OMKM), the Mauna Kea Management Board, and Kahu Kū Mauna to participate in the development of mitigation measures under the Section 106 process.

A formal Section 106 meeting was held on February 1, 2001, in Hilo. NASA held a second formal Section 106 meeting in Hilo on January 16 and 17, 2002. Table 4-1 lists these consultations and other formal meetings that have taken place in connection with the Outrigger Telescopes Project since 1999.

NASA also held informal meetings in Hilo, Kona, and Waimea that were attended by individuals and organizations who stated their position, asked questions, expressed concerns, and received additional information about the Outrigger Telescopes Project. Many of the issues raised in these meetings concerned historic/cultural resources.

On the basis of these formal and informal meetings, and as part of the Section 106 consultation process, NASA prepared proposals for on-site and off-site mitigation of potential impacts to cultural resources for consideration by the SHPD, ACHP, and the other Consulting Parties.

In preparing and developing cultural resource mitigation measures pursuant to the Section 106 process, NASA took into account a wide variety of impacts that may arise during on-site construction, installation, and operation of the Outrigger Telescopes Project. Such impacts included, but were not necessarily limited to, those on biota, the visual landscape, soils and groundwater arising from solid waste and accidental release of hazardous substances, and noise levels. On-site mitigation measures proposed included, but were not limited to, stabilizing the cinder cone slopes, preventing accidental dispersal of debris during and after on-site construction, disposing of excavated material, and reducing noise during on-site construction and operation of the Outrigger Telescopes. Monitoring and other measures that would prevent or minimize deterioration of the visual integrity (i.e., shape and contour) of the cinder cone and its crater were also included. One such measure is the commitment to provide the Consulting Parties with the opportunity to review and comment on the grading and site development drawings and the construction Best Management Practices plan for the proposed project.

TABLE 4-1. OUTRIGGER TELESCOPES PROJECT FORMAL MEETINGS WITH INTERESTED PARTIES

Date	Organization	Location	Type
10/01/99	Hawai‘i Island Burial Council	Kailua-Kona, Hawai‘i	Scheduled meeting
03/28/00	Office of Hawaiian Affairs (OHA) staff	Honolulu, Hawai‘i	Special meeting
03/28/00	OHA Board of Trustees	Honolulu, Hawai‘i	Scheduled meeting
03/28/00	Department of Land and Natural Resources (DLNR) and State Historic Preservation Division (SHPD)	Honolulu, Hawai‘i	Special meeting
03/28/00	Royal Order of Kamehameha I	Hilo, Hawai‘i	Special meeting
03/29/00	Hawaiian Civic Clubs - Kona Chapter	Kailua-Kona, Hawai‘i	Scheduled meeting
03/30/00	Hawai‘i Island Burial Council	Hilo, Hawai‘i	Scheduled meeting
01/30/01	Delegation meets with U.S. Fish and Wildlife Service (USFWS)	Honolulu, Hawai‘i	Special meeting
01/31/01	Delegation meets DLNR and SHPD	Honolulu, Hawai‘i	Special meeting
01/31/01	Delegation meets with Hawai‘i Office of Environmental Quality Control (OEQC)	Honolulu, Hawai‘i	Special meeting
02/01/01	Advisory Council on Historic Preservation (ACHP), Department of Hawaiian Home Lands, Hawai‘i Island Burial Council, OHA, SHPD, W.M. Keck Observatory, Kumu Pono Associates, (Royal Order of Kamehameha I appeared at the start of the meeting)	Hawai‘i Naniloa Hotel, Hilo, Hawai‘i	Section 106 Meeting
02/05/01	Office of Mauna Kea Management (OMKM)	Hilo, Hawai‘i	Special meeting
02/05/01	W.M. Keck Observatory, Public	Hilo, Hawai‘i	Open House Meetings
02/06/01	Mauna Kea Management Board (MKMB)	Hilo, Hawai‘i	Scheduled meeting
02/07/01	W.M. Keck Observatory, Public	Kailua-Kona, Hawai‘i	Open House Meetings
09/27/01	SHPD	Honolulu, Hawai‘i	Special meeting
10/01/01	W.M. Keck Observatory, Public	Kona Outdoor Circle, Kailua-Kona, Hawai‘i	Town Hall Meeting*

TABLE 4-1. OUTRIGGER TELESCOPES PROJECT FORMAL MEETINGS WITH INTERESTED PARTIES (CONTINUED)

Date	Organization	Location	Type
10/02/01	W.M. Keck Observatory, Public	Waimea Community Center, Waimea, Hawaiʻi	Town Hall Meeting*
10/03/01	W.M. Keck Observatory, Public	University of Hawaiʻi at Hilo, Hilo, Hawaiʻi	Town Hall Meeting*
10/04/01	W.M. Keck Observatory, Public	University of Hawaiʻi at Hilo, Hilo, Hawaiʻi	Town Hall Meeting*
01/16/02	All Consulting Parties	Hilo, Hawaiʻi	Section 106 Meeting
01/17/02	All Consulting Parties	Hilo, Hawaiʻi	Section 106 Meeting

* The following organizations either appeared or sent a representative to at least one of the Town Hall Meetings.

Ahahui Ku Mauna
Association of Hawaiian Civic Clubs
Conservation Council for Hawaiʻi
Department of Land and Natural Resources
Hawaiʻi Island Burial Council
Kahu Kū Mauna members
Ka Pae Aina Hawaiʻi
Mauna Kea Anaina Hou
Office of Hawaiian Affairs
Office of Mauna Kea Management member
Royal Order of Kamehameha I

Mitigation measures have been specified in a Memorandum of Agreement (MOA) (see Appendix B of this EIS) and are restated in each environmental resource section where applicable. Signatories to the MOA included NASA, the Advisory Council on Historic Preservation, the Hawaiʻi State Historic Preservation Officer, UH,the California Association for Astronomy (CARA), the California Institute for Technology (Caltech), and Ahahui Ku Mauna (with caveat). Consulting Parties who did not sign the MOA included the Hawaii Island Burial Council, Hui Mālama I Nā Kūpuna o Hawaiʻi Nei, Mauna Kea Anaina Hou, the Office of Hawaiian Affairs, and the The Royal Order of Kamehameha I.

CARA will ensure that any of the MOA provisions relating to on-site construction and installation of the Outrigger Telescopes will be included as provisions in any contracts for on-site construction and installation.

<u>Archaeological Resources</u>. Most of the archaeological resources identified within the Mauna Kea Science Reserve (MKSR) fall into three categories: shrines, adze quarrying and manufacturing localities, and burial sites, as described in Section 3.1.2. No archaeological sites have been identified on Puʻu Hauʻoki.Nonetheless, no area at or near the summit is assumed to be devoid of archaeological resources. This is true even for the proposed site of the Outrigger Telescopes Project, land that was previously disturbed and leveled for construction of the Keck Telescopes. For example, the slope edges could be effectively undisturbed at a shallow depth below the surface and could contain archaeological deposits.

NASA has, therefore, proposed mitigation measures that assume that archaeological resources could be found anywhere on the site. A Draft Burial Treatment Plan has been prepared that stipulates procedures to be followed if burial remains are found during construction. This draft has been submitted for review to the Hawaiʻi Island Burial Council and is provided in Appendix C of this EIS.

If an archaeological resource is discovered during excavation for the Outrigger Telescopes, the mitigation measures as described in the MOA will prevent or reduce adverse effects.

Summit Staging and StockpileAreas. An archaeological survey has been conducted of the summit construction staging and stockpile areas. There are no known historic properties within the area of the Proposed Action. The nearest documented shrine is located more than 250 m (820 ft) from these areas. The summit staging and stockpile areas lie outside the boundary of the Kūkahauʻula historic property.

Hale Pōhaku. An archaeological survey of the construction staging area at Hale Pōhaku has been conducted. There are no known historic properties within the area of the Proposed Action. However, there are archaeological sites and historical architectural resources in the vicinity of the staging area. NASA is aware two shrines located to the south and west at Hale Pōhaku, outside the UH-leased area, about 30.5 m (100 ft) and 48.8 m (160 ft) away from the staging area boundary, respectively. The shrine closest to the proposed use is located on an *aa* wall, which is separated from the staging area by a drainage swale. It would be extremely unlikely for staging area activities to adversely affect either of these shrines. NASA is also aware that archaeological deposits (e.g., lithic artifact clusters) are present throughout the area around Hale Pōhaku. In addition, two stone cabins built in 1936 and 1939 by the Civilian Conservation Corps at Hale Pōhaku under L.W. Bryan's direction are historic architectural resources that may be eligible for the NRHP.

Traditional Cultural Properties. The SHPD has designated Kūkahauʻula, the area of the three summit cones of Mauna Kea, to be a traditional cultural property. Some Native Hawaiians have identified the larger area of Mauna Kea, from the 1,829-m (6,000-ft) elevation to the summit, as a sacred landscape valued for its spiritual significance (Maly 1998; Maly 1999).

The Outrigger Telescopes would be built within the boundaries of the Kūkahauʻula traditional cultural property. The placement of the telescopes on Puʻu Hauʻoki would modify this traditional place, which forms a portion of the landscape regarded as especially sacred by the Native Hawaiian community. Because the Outrigger Telescopes would be placed on ground that has already been disturbed and would be located next to the much larger Keck I and II structures, their impact would be a small increment to the impact that has already occurred.

Traditional Cultural Resources. Traditional cultural resources can be intangible (e.g., traditional gathering practices, ritual observances, burial rites). They are not directly under the purview of the NHPA, but they are included in Section 106 evaluation procedures to the extent that they relate to the significance of specific traditional cultural properties. The American Indian Religious Freedom Act of 1978 protects and preserves the rights of indigenous groups, including Native Hawaiians, to practice their traditional religion, access sites, and conduct ceremonies and traditional rites. Native Hawaiian groups have identified potential impacts to their traditional cultural practices that would result from the on-site construction, installation, and operation of the Outrigger Telescopes Project.

Studies addressing Mauna Kea have identified the following Native Hawaiian concerns regarding the summit area:

- Maintaining the integrity of the spiritual and sacred quality of the summit landscape
- Lack of respect on the part of the astronomy program for Native Hawaiian cultural practices, features, and beliefs
- The effect of increased public use on the summit landscape.

Most Native Hawaiians consulted for Maly's (1999) study expressed the desire that no further development of astronomy facilities occur on Mauna Kea. Potential visual and physical impacts on the *puʻu* (summit cones) were identified as important concerns.

Contemporary Cultural Practices. Contemporary Hawaiian cultural practices identified for the summit area of Mauna Kea include the release of cremated remains and possibly the burial of such remains; prayer and ritual observances, including the construction of new altars; and use of the mountain as a repository of *piko* (umbilical cords) (Maly 1999). Contemporary cultural practices are generally a continuation of traditional practices (with modifications), and impacts on them are similar to impacts identified for traditional cultural practices and values. Concerns include the importance of maintaining access to the summit area for spiritual purposes and maintaining the integrity of the spiritual and sacred quality of the summit landscape.

Native Hawaiian groups have expressed concerns to ACHP that the proposed facilities would limit their access to the summit area (ACHP 2000). Implementation of the Outrigger Telescopes Project would not result in any additional restrictions on accessibility of the summit area to Native Hawaiians.

The presence of large construction equipment, materials, and telescope components at the observatory site and staging area would temporarily increase noise and dust levels and alter the viewscape. These impacts would be short term, restricted to the construction period. They will be mitigated and therefore would have no long-term impact on cultural practices.

Operations Impacts. Operation of the telescopes would not affect archaeological or historic architectural resources, but would have an effect on traditional cultural properties and practices in the summit region. Some of the concerns of Native Hawaiian groups, discussed above in relation to construction and installation impacts, are also relevant during operation of the telescopes. The primary impact would be the continued visual presence of the telescope structures within the Kūkahauʻula traditional cultural property. The visual presence of observatories in general impacts the cultural bond that many Native Hawaiians associate with this historic property. Viewscapes at some locations in the summit region, already impacted by the presence of observatories, would be further altered by the presence of the Outrigger Telescopes. However, because the Outrigger Telescopes would be located next to the much larger Keck I and II structures, their impact would be a small increment to the impact that has already occurred. The operation of the telescopes would not in any way restrict access of Native Hawaiians to the summit region.

Some Native Hawaiians have expressed concern over the possibility of a potential impact to the spiritual and sacred quality of the summit landscape from the disposal of wastewater in sacred areas. The Outrigger Telescopes would use the disposal system now in place for the Keck Telescopes, in which wastewater reaches groundwater beneath the summit and travels to the southwest flank of the mountain without any physical effect on the summit plateau or Lake Waiau (see Section 4.1.3.2).

The project's presence within Kūkahauʻula would indirectly affect the other two traditional cultural properties on the summit plateau, Puʻu Līlīnoe and Waiau, by affecting their view planes. During cultural practices at locations with clear views of the Keck Observatory site, views of the summit area would be further altered to a small extent by the Outrigger Telescopes. This could diminish these practices. The view planes from some areas below the summit would also be altered, but the Outrigger Telescopes would not be visible from many locations below the summit or from the summit itself.

Operation of the Outrigger Telescopes would have no effect on archaeological resources, but would have a small adverse effect on traditional cultural practices associated with the mountain.

On-Site Mitigation Measures. Mitigation measures for cultural impacts associated with the Outrigger Telescopes Project are those set forth in the MOA, including cultural and archaeological monitoring of the construction area, education of workers on the site, mandatory adherence to the construction Best Management Practices Plan, adhering to the Burial Treatment Plan developed for this project, and general historic property protection measures (see Appendix B of this EIS).

Detailed mitigation measures address the need to protect cultural resources in the proposed on-site construction project area, the construction staging area at the summit, at Hale Pōhaku, and at the construction stockpiling area. On-site mitigation measures include, but are not limited to, those described below.

Archaeological Monitoring. CARA will hire a qualified archaeologist, in consultation with the SHPD and OMKM, to monitor all excavation activities; keep a log and map notes of every visit; and to ensure that all project excavation activities follow SHPD Hawaii Administrative Rules for Archaeological Monitoring Studies and Reports. The archaeologist will have the authority to halt work in the vicinity of an inadvertent discovery of human remains or archaeological properties.

Cultural Monitoring. In consultation with NASA and the Consulting Parties, CARA will develop criteria for and select an individual to be the project's Cultural Monitor. This individual will be knowledgeable about Mauna Kea's cultural landscape and the traditions, practices, beliefs, and customs associated with Mauna Kea. The Cultural Monitor will provide cultural orientation to individuals who are associated with the on-site construction and installation of the Outrigger Telescopes. The Cultural Monitor will have unrestricted access for monitoring activities during excavation, other on-site construction, and telescope installation. The Cultural Monitor will keep a log and map notes of every visit. A monitoring plan will be prepared that stipulates the responsibilities of the Cultural Monitor and the procedures to be followed if on-site supervisory or construction personnel act in culturally insensitive ways. The Consulting Parties will be given an opportunity to review the monitoring plan before finalization.

Education. Prior to on-site construction, the contractor(s), supervisors, and all construction workers involved with the Outrigger Telescopes Project will be required to watch a videotape reviewing the historic and sacred qualities of Mauna Kea. They will also be advised that CARA could demand their removal from the project if they fail to comply with the commitments made by NASA and other project participants.

Cultural Interpretation. During on-site construction and installation of the Outrigger Telescopes, OMKM, in consultation with the Hawaii State Historic Preservation Officer (SHPO), will develop and provide interpretive materials on the cultural significance of Mauna Kea. The Consulting Parties will be given an opportunity to review and comment on these materials during their development.

Off-Site Mitigation Measures. Under the terms of the MOA, and as part of its budget for the Outrigger Telescopes Project, NASA will fund an initiative that addresses preservation and protection of historic/cultural resources on Mauna Kea and the educational needs of Hawaiians. This initiative is recorded in the MOA (Appendix B of this EIS).

The mitigation measures developed for the Outrigger Telescopes Project and stipulated in the Section 106 MOA would minimize the impact of the Outrigger Telescopes Project, insuring avoidance of damage to archaeological and traditional cultural resources during construction. Archaeological monitoring and analysis will insure preservation of historic information from any cultural remains that are found, and these remains will then be properly curated. Measures that are part of the Burial Treatment Plan will insure that steps will be taken for proper and respectful retrieval, reburial, and protection of any human remains inadvertently disturbed during construction. There will be no further impact on these types of cultural resources following construction. After construction and mitigation, the presence of the Outrigger

Telescopes will have a small incremental adverse impact to Native Hawaiian cultural practices and the quality of sacredness Native Hawaiians associate with the summit. These impacts cannot be completely mitigated; however, NASA and CARA will attempt to offset this adverse impact by educational programs that will benefit Native Hawaiians.

4.1.2 Biological Resources and Threatened and Endangered Species

4.1.2.1 ROI for Biological Resources and Threatened and Endangered Species

For purposes of this evaluation, the potential impacts to biological resources as a result of implementing the Outrigger Telescopes Project would occur primarily in the four ecological zones described in Section 3.1.3. The boundaries of the ROI would be from the summit of Mauna Kea down to the elevation of the intersection of the Mauna Kea Access Road and Saddle Road.

4.1.2.2 Impacts of the Outrigger Telescopes Project on Biological Resources

On-Site Construction and Installation Impacts.

Summit Area Cinder Cones

Flora. As noted in Section 3.1.3, no floral species have been found on the *Summit Area Cinder Cones*. Lichens, the only botanical resource that inhabit this zone, occur in low abundance adjacent to the W.M. Keck Observatory site, and only the most common lichen species can be found there (Smith and others 1982). Construction of the Outrigger Telescopes would disturb 0.008 hectares (ha) (0.019 acres (ac)) of habitat on the sloped portion of Puʻu Hauʻoki. This represents a very small fraction of the available lichen habitat on Mauna Kea. Consequently, on-site construction and installation of four, and possibly up to six, Outrigger Telescopes would have no adverse impact to the floral component of the natural environment of the *Summit Area Cinder Cones*. There would be no significant impact on the flora of the *Summit Area Cinder Cones* as a result of the construction and installation of the Outrigger Telescopes.

Fauna. There are at least 11 species of indigenous Hawaiian arthropods that inhabit the *Summit Area Cinder Cones* (Howarth and others 1999). The area of the W.M. Keck Observatory site that was leveled for construction of the Keck I and Keck II Telescopes is subject to daily activities such as vehicle parking and foot traffic, and therefore harbors no substantial populations of any of the 11 Hawaiian arthropod species known to inhabit the *Summit Area Cinder Cones* (see Section 3.1.3). Almost all on-site activities would be confined to this previously leveled area.

There is concern that some construction activities could harm Wēkiu bugs that live in cinder habitats adjacent to the proposed construction site. On-site construction and installation of Outrigger Telescope 1 would occur on a gradually sloped portion of the leveled area that was previously graded and disturbed during construction of the Keck I and Keck II Telescopes (see Figure 2-6). No Wēkiu bugs were found in that leveled area during the 1997/98 sampling effort (Howarth and others 1999) (see Section 3.1.3). Wēkiu bugs do inhabit the cinder adjacent to this site. While this habitat and its porous structure are fairly stable, it is possible that disturbance can degrade it. Side-casting of unsorted materials during construction of Outrigger Telescope 1 could bury Wēkiu bug habitat and the resident population. However, habitat protection procedures outlined in the Wēkiu Bug Mitigation Plan, such as protective barriers and educational signage, would minimize side-casting of materials into Wēkiu bug habitat, and thus minimize habitat disturbance.

On-site construction and installation of Outrigger Telescopes 2, 3, and 4, would involve activities on the previously disturbed sloped wall area of the cinder cone immediately adjacent to the leveled area of the W.M. Keck Observatory site. The sloped areas of the cinder cone wall adjacent to the W.M. Keck Observatory site received substantial side-cast material during the construction of the Keck I and Keck II Telescopes. The surface structure on these slopes has recovered to some degree, and some of these slopes were the locations of the densest populations of Wēkiu bugs measured during the 1997/98 Mauna Kea arthropod assessment (Howarth and others 1999).

On-site construction and installation of air pipes and retaining walls necessary for slope stability at Junction Box 5 (JB-5) and at Outrigger Telescope 3 would displace 0.008 ha (0.019 ac) of this previously disturbed habitat. Table 4-2 summarizes these displacements.

Specifically, at JB-5, the air pipe and retaining wall would extend into and displace about 0.002 ha (0.005 ac) of the sloped area habitat (CARA 2001g) (see Figure 2-12). At Outrigger Telescope 3 the air pipe and retaining wall would displace about 0.006 ha (0.014 ac) of the sloped outer wall area that is Wēkiu bug habitat (see Figure 2-13). Outrigger Telescope 4 would require placement of its air pipe and a retaining wall within a steeply sloped portion of previously disturbed outer cinder wall area on the northeastern side of the W.M. Keck site (see Figure 2-14). However, the 1997/98 arthropod assessment found no Wēkiu bugs in this area.

Displacement and disturbance of habitat by construction of the Outrigger Telescopes has the potential for a small to moderate impacts on local populations of Wēkiu bugs. Proposed restoration efforts would encompass an area of at least 0.024 ha (0.057 ac), resulting in a habitat restoration ratio of at least 3:1 when compared to the amount of habitat area that would be displaced by on-site construction and installation of Outrigger Telescope 3 and JB-5. If successful, the net result of habitat restoration would be an increase in the amount of Wēkiu bug habitat on Puʻu Hauʻoki.

Except for the habitat displacement described above, almost all of the on-site construction and installation activity for Outrigger Telescopes1 through 4, and all of those activities for Outrigger Telescopes 5 and 6, would occur within the leveled area that was previously graded and disturbed during construction of the Keck I and Keck II Telescopes (see Figure 2-6). That activity will not directly disturb Wēkiu bugs, but impacts could occur as a result of some construction related activities. Construction materials, trash, and other substances that migrate onto the slopes of Puʻu Hauʻoki would have a small impact on Wēkiu bug habitat. The Wēkiu Bug Mitigation Plan requires that construction trash containers be tightly covered and that construction materials stored at the site be covered with tarps, or anchored in place to prevent materials from being dispersed by wind.

Construction of the proposed Outrigger Telescopes would involve excavations for dome and junction box foundations, and trenching for air and light pipes. This activity has the potential for creating dust.

TABLE 4-2. LOCATION AND AREA OF WĒKIU BUG HABITAT DISTURBANCE

Location	Area of Wēkiu Bug Habitat Disturbance
Junction Box 5	0.002 ha (0.006 ac)
Outrigger Telescope 3	0.006 ha (0.014 ac)
Total	0.008 ha (0.019 ac)

Summit wind velocity usually ranges between 16 and 24 km per hour (10 and 15 miles per hour) with speeds exceeding 160 km/h (100 mph) during severe storms. Dust, ash, and cinder disturbed during excavation can be carried by wind and deposited on adjacent slopes. Excessive dust could have a substantial impact on Wēkiu bug habitat. The Wēkiu Bug Mitigation Plan provides for dust control by: applying water to excavation sites and cinder stockpiles; suspending dust-generating activities during high winds; and using environmentally friendly soil-binding stabilizers. Thus, only a small amount of dust would be generated from on-site construction activities, with only small impacts to Wēkiu bug habitat.

Hazardous substances may be required during on-site construction of the Outrigger Telescopes. Paints, thinners, solvents, and fuel may be transported to the site for specific construction activities. The Wēkiu Bug Mitigation Plan and its provisions incorporated into the Best Management Practices Plan (Appendix F) requires contractors to minimize the amount of on-site paints, thinners, and solvents, and to clean painting and construction equipment off-site in order to reduce the potential for spills. This would reduce the likelihood of accidental spills and minimize potential impacts to Wēkiu bug habitat.

Arthropod species introduced outside their natural range represent a threat to natural systems because they can deplete native arthropod food resources and prey on native species, sometimes driving them to extinction. Alien species that successfully establish populations within the Mauna Kea Science Reserve (MKSR) could out-compete or exclude native species, such as the Wēkiu bug, lycosid wolf spider, and other native resident arthropods. Alien arthropods can arrive at the summit by two general pathways. First, alien species already on the island can spread to new localities. Second, alien species can arrive with shipping crates and containers. Earthmoving equipment, large vehicles and trailers often sit at storage sites for several days or weeks between jobs. Most of these storage sites are located in industrial areas and usually support colonies of ants and other alien arthropods. These species often use stored equipment as refuges from rain, heat, and cold. Ants will colonize mud and dirt stuck to earthmoving equipment and could then be transported to uninfested areas. Spiders occupy stored equipment, looking for food or escaping predation by hiding in protected niches. Once transported to the summit, these species could migrate to Wēkiu bug habitat. The probability for the introduction of a serious predator is small, but the establishment of just one alien species could have substantial impacts on native arthropods. Earthmoving equipment, large trucks, tractors and other heavy equipment, containers, and construction materials would be pressure washed and inspected for invasive alien arthropods before proceeding up the Mauna Kea Access Road. A qualified entomologist will monitor the construction site for alien species, and if any are found appropriate measures would be taken. The pressure washing, inspections, and monitoring would reduce the probability for invasive alien arthropod introductions that could result from the construction of the Outrigger Telescopes, and thus the probability for impacts is small.

In summary, mitigation measures associated with on- site construction and installation of the Outrigger Telescopes would make potential impacts to Wēkiu bugs and their habitat small. Because other species of Hawaiian arthropods known to inhabit the *Summit Area Cinder Cones* occur in equal abundance on other summit area cinder cones, the impact to any of these would likely be small and not significant.

<u>*Below the Summit Area Cinder Cones* -</u> There are three off-site activities that would occur away from the W.M. Keck Observatory site that could potentially impact the flora and fauna *Below the Summit Area Cinder Cones*:

- Storage of construction materials and equipment at the summit staging area,
- Cinder screening and washing at the summit staging area, and
- An increase in vehicle traffic on the Pu'u Hau'oki Detour Road.

<u>Flora</u>. Vegetation is sparse within the elevations of the Mauna Kea Science Reserve *Below the Summit Area Cinder Cones*. Construction and installation activities of the Outrigger Telescopes *Below the Summit Area Cinder Cones* would be confined to approved construction lay down and storage areas largely uninhabited by floral species, lichens, or mosses. Habitats for the fern, *Cystoperis douglasii,* regarded as a species of concern by the USFWS, lichens, and mosses occur adjacent to the summit staging area. Ferns, lichens and mosses that inhabit these areas could potentially be impacted if excessive dust is generated from activities at the staging area. Dust generation from cinder screening would be minimized because washing would happen concurrently. Other dust generation from vehicle traffic would be small. In addition, ferns are not abundant there and fern populations *Below the Summit Area Cinder Cones* are not expected to be affected by Outrigger Telescopes construction and installation activities. Lichens and mosses are more abundant elsewhere. Thus, Outrigger Telescopes construction and installation activities would have a small, localized impact on the vegetation, but no significant impact on the overall flora *Below the Summit Area Cinder Cones.*

<u>Fauna</u>. The staging area near the summit is not located in Wēkiu bug habitat, but there may be Wēkiu bug habitat nearby. The use of the staging area should not impact Wēkiu bugs *Below the Summit Area Cinder Cones* when the mitigation measures are followed (e.g., trash control, dust control, material control, inspections for alien arthropods, monitoring). For example, vehicles generating dust on the unpaved portion of the Pu'u Hau'oki Detour Road could impact adjacent habitat, but when the vehicles follow the recommended speed limit of 8 km (5 mi) per hour, only a small amount of dust would be generated that would have no impact on Wēkiu bug habitat. Cinder screening and washing would happen concurrently and therefore, should not generate excessive dust. Overall, there would be no impact on Wēkiu bugs or their habitat *Below the Summit Area Cinder Cones* from construction and installation of the Outrigger Telescopes. The mitigation measures in the Wēkiu Bug Mitigation Plan would also protect the habitat of the other resident species. The construction and installation of the Outrigger Telescopes would therefore have no impact on the fauna *Below the Summit Area Cinder Cones.*

Silversword/Alpine Shrub Zone

Flora. Traffic along the Mauna Kea Access Road in the lower elevation areas, particularly the heavy truck traffic that would be associated with the Outrigger Telescopes Project, could result in some dust deposition on roadside vegetation in the *Silversword/Alpine Shrub Zone*. This is expected to be short-term and temporary given that the increase in daily traffic would amount to only about 15 round trips each day, and heavy vehicle traffic would be confined largely to the mobilization and demobilization periods of the on-site construction and installation phase. The Mauna Kea silverswords (*Argyroxiphium sandwicense)*, is the only Federally-endangered plant species known to inhabit Mauna Kea above 3,132 m (9,000 ft). One plant located next to the road in the switchback area could be impacted by dust generated from vehicle traffic. The only other known population of this species occurs at the Wailuku river basin outside of the MKSR, 4-km (2.5-mi) away from the Mauna Kea Access Road and is unlikely to be disturbed by dust. No other plant species are likely to be impacted by vehicle traffic on the road. Consequently, vegetation in the *Silversword/Alpine Shrub Zone* would not be impacted by construction and installation of the Outrigger Telescopes.

Fauna. The endangered Hawaiian seabird, *ʻuaʻu*, is suspected to occur at mid-elevations on Mauna Kea, near Puʻu Kanakaleonui, more than 4.8 km (3 miles) from the unpaved portion of the Mauna Kea Access Road. It is unlikely that there would be any adverse impacts to this species or its habitat as a result of the construction and installation of the Outrigger Telescopes. There are no other species known to inhabit the *Silversword/Alpine Shrub Zone* that could be impacted by vehicle traffic. There would be no adverse impacts to the fauna at lower elevations within the MKSR.

Māmane/Subalpine Forest Zone

Flora. Construction activities for the Outrigger Telescopes in the *Māmane/Subalpine Forest Zone* would be limited to the Hale Pōhaku staging area. The area would be used only for storing construction equipment and materials and activities would be limited to the gravel-covered staging area. No indigenous plants inhabit the staging area and there would be no impact on native flora at this site.

Fauna. Two federally endangered bird species, the *palila* and the *ʻakiapolaʻau,* inhabiting the *māmane* subalpine forest near the Hale Pōhaku staging area. There are no food resources on the site and it is unlikely that these birds would visit there. However, the *māmane* forest surrounding the construction staging area is dry and susceptible to fire, and once started, a fire could be difficult to control. Fire prevention and suppression measures that are part of the Best Management Practices would make this potential for fire damage small.

Although several hundred arthropod species inhabit the *māmane* subalpine forest, none are known to occur exclusively near the Hale Pōhaku staging area. Because of increased vehicle traffic and storage of equipment and construction materials, it is possible that nonindigenous species could be introduced to the surrounding *māmane* subalpine forest. To mitigate this possibility, earthmoving equipment, large trucks, tractors and other heavy equipment, containers, and construction materials would be inspected for invasive alien arthropods before proceeding up the Mauna Kea Access Road. The inspections would reduce the probability for invasive alien arthropod introductions as a result of the construction activity of the Outrigger Telescopes, and thus make the potential for impacts small.

Summary of the Impacts of the On-Site Construction and Installation of the Outrigger Telescopes Project on Biological Resources. Construction and installation of four, and possibly up to six, Outrigger Telescopes would have no significant impacts on the biological resources of the four ecological zones.

Operation Impacts.

All Ecological Zones

Flora and Fauna. CARA has already begun to implement some of the protection measures outlined in the Wēkiu Bug Mitigation Plan for current Observatory activities. These will continue to be followed, and would make the potential impacts from Outrigger Telescope operations small.

The small amount of additional traffic to the summit that would be associated with Outrigger Telescopes would generate negligible amounts of dust, reducing the potential for adverse impacts. Housekeeping and trash management can increase disturbance to habitats. Retrieving debris from sensitive areas can destroy the fragile structure of the cinder habitat. Shipments to the W.M. Keck Observatory site increase the potential introduction of alien arthropods to the summit area that may prey on native resident species thereby reducing their populations. Spills of toxic materials could spread into adjacent habitats, making them unsuitable for resident species.

Summary of the Impacts of the Operation of the Outrigger Telescopes Project on Biological Resources. Operation of the Outrigger Telescopes would have no foreseeable adverse effects on species on the *Summit Area Cinder Cones* and *Below the Summit Area Cinder Cones*. Operation impacts below these two areas are likely to be small and would also not adversely affect plant or animal resources within the lower elevations of the MKSR. No Federally listed threatened or endangered species of or animals would be adversely affected by operation of the Outrigger Telescopes.

Mitigation Measures.

Given that on-site construction and installation of the Outrigger Telescopes would displace about 0.008 ha (0.019 ac) Wēkiu bug habitat; and (2) other on-site construction, installation, and operation activities could also impact the Wēkiu bug, a Wēkiu Bug Mitigation Plan (see Appendix D of this EIS) has been developed to reduce or avoid those impacts. This plan includes measures to minimize habitat disturbance by: a) erecting temporary barriers to prevent loose material from being sidecast and impacting Wēkiu bug habitat downslope during on-site construction and installation activities at JB-5 and Outrigger Telescopes 1 and 3; b) controlling dust, hazardous materials, and trash; and c) reducing the potential for introduction of alien arthropods during on- site construction and installation by inspecting vehicles, equipment and materials before they proceed up the Mauna Kea Access Road, and by monitoring for and controlling alien species. The Wēkiu Bug Mitigation Plan addresses all of the potential stresses to the natural ecosystem on the summit of Mauna Kea from the proposed Outrigger Telescopes Project and would reduce potential impacts on all the native Hawaiian arthropods known to inhabit the summit area. When all the protection measures are implemented, the magnitude and significance of the changes as a result of the project would be extremely small.

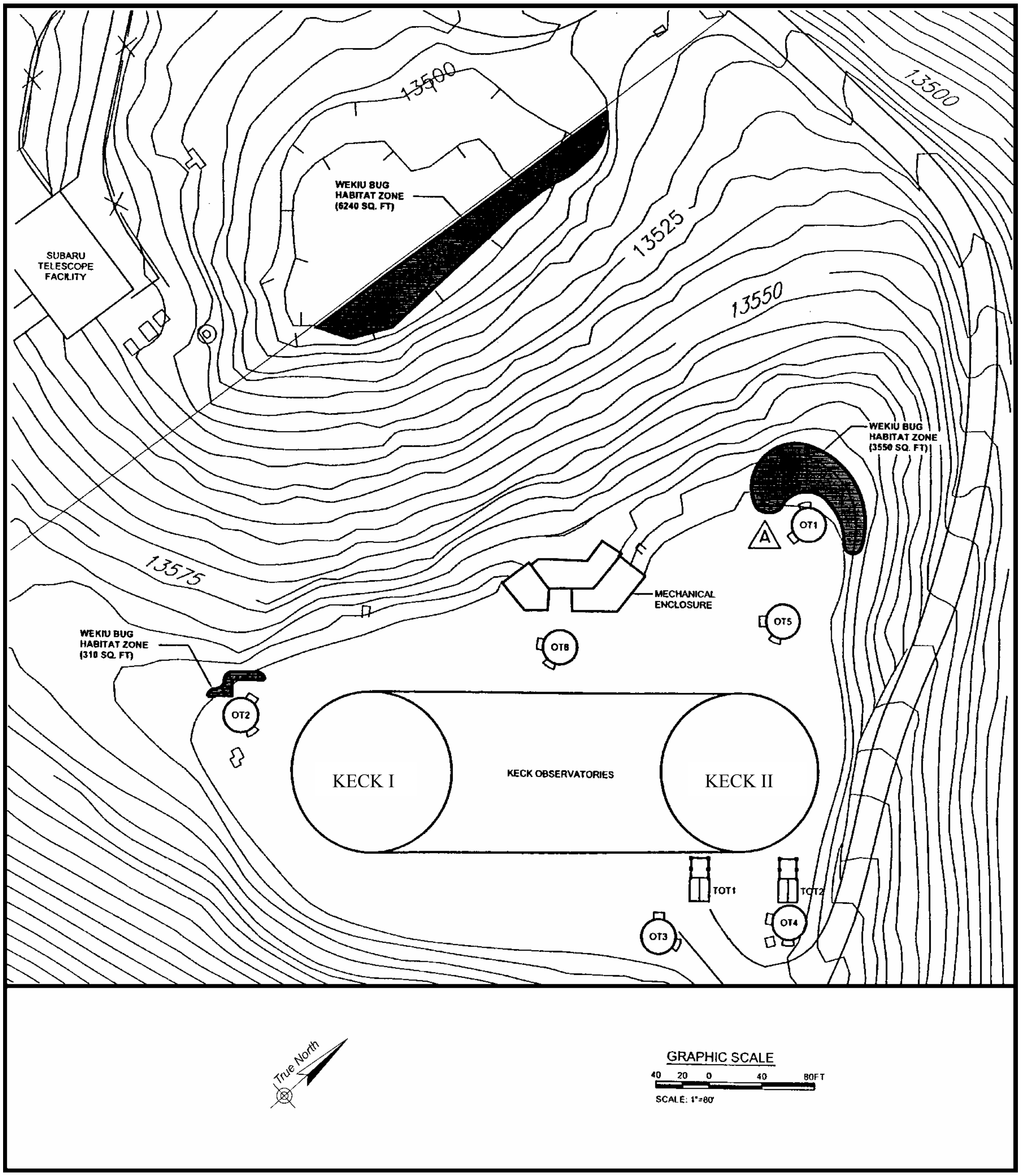
In addition to habitat protection, the plan calls for Wēkiu bug habitat restoration as mitigation, to replace the habitat that would be displaced by on-site construction and installation of Outrigger Telescope 3 and JB-5. At least 0.024 ha (0.057 ac) of habitat would be restored in areas disturbed by previous construction activities. The overall habitat displacement of the Outrigger Telescopes Project would be very small (an increase of about 0.06 percent), and there is potential to increase the amount of available habitat through restoration.

The Wēkiu Bug Mitigation Plan and its requirements will be incorporated into Outrigger Telescopes on-site construction and installation contracts. That plan includes a comprehensive Wēkiu Bug Monitoring Plan (see Appendix E of this EIS) that calls for monitoring contractor compliance to the mitigation plan. CARA will implement the monitoring plan, and enforce compliance with the mitigation plan. In addition, a qualified entomologist would be on-site monthly to monitor implementation of the proposed mitigation measures and measure the effectiveness of habitat protection and restoration efforts.

Development of the Wēkiu Bug Mitigation Plan resulted in design changes that prevent or reduce the disturbance of Wēkiu bug habitat. Outrigger Telescope 1 has been relocated about 4-m (13.2-ft) closer to the Keck II Telescope than originally proposed and removed from Wēkiu bug habitat. JB-5 has been relocated to less than 0.9 m (3 ft) from Outrigger 2, minimizing disturbance to the inner crater wall. Retaining walls would be used at Outrigger Telescope 3 and JB-5 to further minimize habitat displacement. The retaining walls would be constructed of cinder- colored masonry or reinforced concrete to blend with the surrounding land. See Section 2.1.3.4 for a history of the engineering design changes. As a result of the Mitigation Plan and the Project's concern for the Wēkiu bug habitat, the original plans, in which 0.067 ha (0.17 ac) were displaced, have been changed so that only 0.008 ha (0.019 ac) are displaced.

A key element of the Wēkiu Bug Mitigation Plan is restoration of Wēkiu bug habitat. The habitat restoration portion of this plan has been developed in conjunction with the USFWS and other scientists familiar with Wēkiu bug ecology, and would restore habitat adjacent to the W.M. Keck Observatory site and at the bottom of the Pu‘u Hau‘oki crater (see Figure 4-1). The proposed restoration effort would encompass an area of at least 0.024 ha (0.057 ac). The intent is to make it possible for Wēkiu bugs to establish resident populations within the restored areas.

The proposed restoration activity would use cinder excavated for the Outrigger Telescopes as the habitat restoration medium. All cinder not used for backfill or site grading would be screened to obtain suitably sized cinder and washed to remove excess dust. Cinder screening and washing would occur at the summit staging area. The screened and washed cinder would be spread at proposed restoration areas in a layer about 30-cm to 46-cm (12- in to 18-in) deep to accomplish the 3:1 restoration commitment. This is believed to be within the desired depth range for Wēkiu bug habitation (Pacific Analytics, LLC 2000). Cinder on the margins of the restored areas would be placed to ensure that contact with the existing habitat would be established. Restoration of the areas adjacent to Outrigger Telescope 1 and JB-5 would be given greater priority than restoration of the area on the floor of Pu‘u Hau‘oki crater (Figure 4-1). Since the size of the restoration area would be limited by the amount of available cinder excavated during construction of the Outrigger Telescopes,



Source: W.M. Keck Observatory 2001

FIGURE 4-1. PROPOSED WĒKIU BUG RESTORATION HABITAT FOR THE OUTRIGGER TELESCOPES PROJECT

the size of the restoration area on the floor of Pu‘u Hau‘oki crater may be reduced in order for areas adjacent to Outrigger Telescope 1 and JB-5 to be restored.

Restoration would continue until the supply of suitable- sized cinder is exhausted, or the restoration of all three areas is complete.

The habitat restoration protocol has been based on all of the scientific information available about the habitat needs of the Wēkiu bug. The protocol considered the following information.

1. Wēkiu bugs appear to prefer habitat made of loose accumulations of cinder 1 centimeter (cm) (½ in) in size or larger (Howarth and Stone 1982). Studies have found the highest concentration of Wēkiu bugs in this type of habitat (Howarth and Stone 1982; Howarth and others 1999, Polhemus 2001, Englund and others 2002). This information leads to a conclusion that restored habitat consisting of 30 to 46 cm (12 to 18 in) of loose 1 cm (½ in) size or larger cinder will be acceptable to Wēkiu bugs.

2. Wēkiu bug habitat occurs on portions of crater floors and on sloped crater walls in summit cinder cones (Howarth and Stone 1982; Howarth and others 1999). In 1982, 6,230 Wēkiu bugs were collected on the crater floor of Pu‘u Wēkiu and 430 Wēkiu bugs were collected on the crater floor of Pu‘u Hau‘oki. During the 1997/98 arthropod assessment, Wēkiu bugs were found on the crater floor of Pu‘u Wēkiu and Pu‘u Hau‘oki, and on the inner slopes of Pu‘u Hau‘oki adjacent to the crater floor. Since suitable habitat does not currently exist on the crater floor of Pu‘u Hau‘oki, Wēkiu bugs from the adjacent inner slopes apparently migrate to the crater floor. This information leads to a conclusion that Wēkiu bugs would likely find and occupy restored habitat on the crater floor of Pu‘u Hau‘oki.

3. Given sufficient time, Wēkiu bug habitat appears to recover from disturbance. Of all sites sampled during the 1997/98 arthropod assessment, habitat on the slopes below the W.M. Keck Observatory site that was presumably disturbed during site preparation and construction contained the highest concentration of Wēkiu bugs. This information leads to a conclusion that Wēkiu bugs would eventually occupy restored habitat.

Given the information above, it is believed that habitat restoration will succeed in expanding the current Wēkiu bug population. At NASA's initiative, consultations were conducted with the USFWS and biologists familiar with Wēkiu bug ecology to determine an appropriate experimental design to test the effectiveness of habitat restoration. As a result of those consultations the habitat restoration protocol was modified to include another component. In addition to monitoring restored areas, unrestored control sites adjacent to restored areas will also be monitored to better determine if restoration was successful.

CARA would implement the Wēkiu Bug Mitigation and Monitoring Plans and habitat restoration. The restored habitat would be monitored quarterly by a qualified entomologist for 18 months following completion of the proposed habitat restoration to determine if the Wēkiu bug reestablishes in those areas. Monitoring of Wēkiu bug populations would continue semiannually for no less than five years following completion of the construction of the Outrigger Telescopes, and on an annual basis thereafter for the term of the CDUP.

Baseline monitoring of Wēkiu bugs in Pu‘u Hau‘oki and Pu‘u Wēkiu was started in February 2002, and has continued quarterly since then. As a result of that effort, modifications to the trapping system have reduced mortality to near 2 percnet, a substantial reduction from the 40 percent average mortality before modifications were made, and much less than the 100 percent mortality experienced with ethylene-glycol traps used prior to 1997. On-going efforts are being made to further reduce mortality in live-traps. Progress reports on the monitoring results will be submitted semiannually to the DLNR, OMKM, and the Bishop Museum for no less than five years following completion of construction of the Outrigger Telescopes, and on an annual basis thereafter for the term of the CDUP. During the habitat monitoring, efforts would be made to gather weather data related to Wēkiu bug monitoring from a location near the area of monitoring.

The Wēkiu Bug Monitoring Plan specifies methods for measuring the results of actions undertaken in accordance with the Wēkiu Bug Mitigation Plan and the subsequent changes in the Wēkiu bug population and habitat. Two types of monitoring will be implemented: compliance monitoring and effectiveness monitoring. Compliance monitoring investigates the extent to which contractors, operators, managers, and visitors comply with Wēkiu bug protection guidelines and rules. Effectiveness monitoring investigates the changes in Wēkiu bug habitat and population that happen concurrent with and subsequent to construction of the Outrigger Telescopes. This includes monitoring of habitat restoration efforts. The Wēkiu Bug Monitoring Plan specifies tasks, schedules, and sampling protocols for both types of monitoring.

The compliance monitoring section is based on the commitments made in the Wēkiu Bug Mitigation Plan to protect Wēkiu bugs and their habitat. Compliance monitoring would measure adherence to guidelines set for: slope stability and habitat protection; habitat restoration; control of dust and trash; avoiding spills of hazardous materials; and cleaning and inspecting construction equipment and material before transport to the summit. Monitoring for compliance will give the operators, oversight agencies, and the public the information necessary to ensure that natural resources are protected during the Outrigger Telescopes Project.

Effectiveness monitoring would investigate the changes in the Wēkiu bug population and habitat that happen concurrent with construction and operation of the Outrigger Telescopes. Effectiveness monitoring measures the success of the environmental controls adopted and mitigation treatments undertaken in conserving the Wēkiu bug.

As part of the Outrigger Telescopes Project implementation and mitigation, NASA will fund a Wēkiu bug autecology study, to gather more information about habitat requirements, life cycle, nutritional requirements, and breeding behaviors of this unique bug. New information could be used to modify the habitat restoration protocol to increase its effectiveness.

Where applicable, all participants in the proposed Outrigger Telescopes Project will comply with the Wēkiu Bug Mitigation Plan, the Wēkiu Bug Monitoring Plan, the NHPA Section 106 MOA, the Construction Best Management Practices Plan and all other existing plans and agreements designed to protect the natural resources of Mauna Kea.

<u>Summary of the Impacts of the Outrigger Telescopes Project on Biological Resources</u>. When the Wēkiu Bug Mitigation Plan and the Wēkiu Bug Monitoring Plan are implemented, the anticipated adverse impacts to the biological resources within the ROI as a result of the Outrigger Telescopes Project would be small. Through restoration, the amount of Wēkiu bug habitat adjacent to the W. M. Keck Observatory

would increase. The Outrigger Telescopes Project would have no significant impacts on the biological resources within the ROI.

4.1.3 Hydrology, Water Quality, and Wastewater

4.1.3.1 ROI for Hydrology, Water Quality, and Wastewater

For purposes of this evaluation, the potential impacts to hydrology, water quality, and wastewater as a result of implementing the Outrigger Telescopes Project are the pathways for the flow of surface and subsurface water. The routes and extent of pathways of surface runoff are identifiable by topography. The subsurface pathways, including travel downward through unsaturated lava and then lateral travel in groundwater, extend all the way to the island's shorelines.

4.1.3.2 Impacts of the Outrigger Telescopes Project on Hydrology, Water Quality, and Wastewater

On-Site Construction and Installation Impacts. Activities with the potential to affect hydrology, water quality, and wastewater would occur during the on-site construction and installation phases of the Project. Three principal activities could potentially have environmental impact during construction: (1) the process of washing cinder for Wēkiu bug habitat restoration in Submillimeter Valley directly south of Pu'u Hau'oki, (2) using water to control dust, and (3) accommodating the water supply and wastewater treatment and disposal needs of construction workers. Each of these is addressed in the following sections.

Cinder Washing for Wēkiu Bug Habitat Restoration. An estimated 2,752 cubic meters (m^3) (3,600 cubic yards (yd^3) or 97,200 cubic feet (ft^3)) of material at the W.M. Keck Observatory site would be excavated for the installation of pipes, junction boxes, foundations and instrument enclosures for the Outrigger Telescopes. About one-half of this material would be used as backfill for the trenches and the remainder transported to Submillimeter Valley for screening and washing cinders for use in the Wēkiu bug habitat restoration. It is anticipated that 18 percent (249 m^3 (8,800 ft^3)) of the screened and washed cinder would be suitable for habitat restoration. Washing this cinder would require about one gallon per cubic foot, meaning that the total washwater used would be less than 38 kiloliters (kl) (10,000 gal). Only potable water would be used and it would be trucked to the screening site on the mountain. Some of this wash water would evaporate during washing and drying. The remainder would percolate downward beneath the washing area. This percolating water would contain suspended particulates from the washing process, which would be removed by natural filtration in the downward travel of the water and retained in the unsaturated rock mass.

From a hydrologic perspective, the total volume of water used in the washing process would be inconsequential: the entire 38 kl (10,000 gal) of wash water would represent less than 0.014 percent of the 13 cm (5 in) of average annual rainfall in the 212-ha (525 ac) area of the Astronomy Precinct on the summit area of Mauna Kea. Considering the small volume of wash water and the natural filtration that would occur as it percolates through the cinder removing particulates, no significant hydrologic or water quality impacts would occur.

Water Use for Dust Control. Water would be used to control dust during excavation for trenches and foundations. It would be trucked by the contractor to W.M. Keck Observatory and applied as needed. As an order of magnitude estimate, it is assumed that this water use would amount to 2 kiloliters per day (klpd) (500 gal per day (gpd)) for 3 days a week through the first 6 months of the 24-month construction period. It is estimated that the total water volume would amount to 148 kl (39,000 gal). This volume would be equivalent to 0.055 percent of the average annual rainfall of 13 cm (5 in) in the Astronomy Precinct.

Some of the water applied for dust control would evaporate. The remainder would percolate downward, initially carrying with it suspended particulates created during the excavation process. During this downward subsurface movement, these suspended solids would be intercepted and retained in the unsaturated rock mass; the naturally clarified water would continue downward, ultimately reaching the underlying groundwater body. As with the cinder washing for the Wēkiu bug habitat restoration, there would be no significant hydrologic or water quality impact from this process.

<u>Water Use and Wastewater Treatment and Disposal for Construction Workers</u>. Two work crews would be required for on-site construction and installation of the Outrigger Telescopes Project: a work crew of up to 15 individuals would be on site for the full 24-month construction period at the W.M. Keck Observatory site for installation of the Outrigger Telescopes and an integration and testing crew of up to 15 individuals would be on site for the final 5 months. To assess the impact of water use by these workers over the 24-month construction period, the following assumptions have been made:

- All workers would be housed at Hale Pōhaku
- Water supply and wastewater collection and disposal for workers at the summit would be handled by portable facilities provided by the contractor. Since these portable facilities would be self-contained, they would create no hydrologic or water quality impacts
- The construction contractor would retain a licensed waste hauler to pump out the portable toilets periodically for off-site disposal at an approved treatment facility (see Appendix F).

Under these assumptions, hydrologic, water quality, and wastewater impacts during construction would be limited to water use and wastewater disposal for construction workers staying at Hale Pōhaku. The number of individuals staying at Hale Pōhaku at present varies substantially, but averages 38 per day. Based on water delivery records, water use at Hale Pōhaku averages about 379 liters per day (lpd) (100 gpd) per person or 14.4 klpd (3,800 gpd) per year. As a first order approximation, it is reasonable to assume that essentially all of this water becomes wastewater disposed of among Hale Pōhaku's seven cesspools and two septic systems. Relative to the average number of Hale Pōhaku residents, construction workers for the Outrigger Telescopes Project would increase the resident population, water use, and wastewater generation as shown in Table 4-3. The additional water supply for construction workers would be trucked to Hale Pōhaku.

The impacts of the subsurface discharge of wastewater can be approximated using the following conservative assumptions:

- Raw wastewater disposed in the facility's cesspools and septic systems would have a total nitrogen concentration of 40 milligrams per liter

TABLE 4-3. WATER USE AND WASTEWATER GENERATION DURING CONSTRUCTION OF THE OUTRIGGER TELESCOPES

Period of Construction	Number of Construction Workers	Total Residing at Hale Pōhaku	Percent Increase	Water Use and Wastewater Generation	
				Addition Due to Construction Workers (gpd)	Total Flow (gpd)
First 15 months	15	53	39	1,500	5,300
Final 5 months	27	65	71	270	6,500

(mg/l) and total phosphorus of 15 mg/l. Nutrients, such as nitrogen and phosphorus, in wastewater are the primary concern for groundwater contamination and are a good indicator of such contamination. The concentrations assumed herein are typical for domestic wastewater.

- No removal of these nutrients would occur in either the cesspools or the septic systems; that is, all of the nutrients in the wastewater would percolate downward toward groundwater in the otherwise clarified wastewater. Depending on the bedding material of the cesspools and leach fields, actual nutrient removal rates are likely to be in the range of 20 to 50 percent.
- Since there is no evidence of shallow (perched) groundwater beneath and/or downslope of Hale Pōhaku, the percolating wastewater would travel downward to the groundwater at depth (refer to Section 3.1.4.4 for a description of this occurrence).
- The drop in elevation of the percolating wastewater through the vadose zone to the underlying groundwater could be on the order of 914 to 2,134 m (3,000 to 7,000 ft), which could take from several months to several years. Such movement through cracks and clinker zones would act as a natural "trickling filter" treatment process to break down and/or adsorb nutrients. Actual nutrient reductions would likely be more than 90 percent. However, for this conservative assessment, no nutrient removal is assumed to occur.
- Given Hale Pōhaku's location relative to Mauna Kea's south rift zone, once the wastewater reaches the underlying groundwater, it would move in an easterly (downgradient) direction generally toward Hilo Bay. Depending on its route, it would be moving in the Onomea (No. 80204) or Hilo (No. 80401) State-designated aquifers.
- As the wastewater travels over the more than 32-km (20-mi) to the nearest wells (either the Kaieie Mauka well (No. 4708-03) in the Onomea Aquifer or Saddle Road Well "A" (No. 4110-01) in the Hilo Aquifer) there would be lateral dispersion of the wastewater plume that could be on the order of 10 degrees. If just 5 degrees is assumed to be conservative, the plume width after traveling 32 km (20 mi) would be about 2.8 km (1.75 mi).
- It would take the wastewater about 30 to 100 years to travel the 32-km (20-mi), based on an average permeability of 457 m (1,500 ft) per day, a gradient of 0.3 to 0.9 m per km (1 to 3 ft per

mi), and an effective porosity of 10 percent. It is assumed that no nutrient removal or decomposition would occur over this decades-long travel time. In actuality, virtually complete decomposition and/or adsorption of the remaining nutrients would very likely occur.

- Natural rates of groundwater movement in the Onomea and Hilo Aquifers are very high. Based on calculations in George A.L. Yuen & Associates (1992) adopted by the State Commission on Water Resource Management, groundwater flowrates in the two aquifers amount to 44 and 70 million gpd per coastal mile, respectively. Over the 2.8-km (1.75-mi) width of the wastewater plume, 19 to 25 klpd (5,000 to 6,500 gpd) of wastewater from Hale Pōhaku would be diluted by a factor of 12,000 to 25,000. Arriving concentrations of nitrogen and phosphorus, because of dilution alone with no removal or decomposition occurring anywhere en route, would be, at the low end of the dilution, 0.003 mg/l as nitrogen and 0.001 mg/l as phosphorus. Background levels of these nutrients in pristine Hawaiian groundwater are typically several hundred or more times higher than this. The potential impact based on this series of conservative assumptions is insignificant. When actual nutrient removal is considered, there is no impact.

Operation Impacts. Two aspects of the Outrigger Telescopes operations must be considered for their potential hydrologic and/or water quality impacts: (1) change in surface runoff from the W.M. Keck Observatory site, and (2) generation and disposal of domestic wastewater. These are discussed in the following sections. All other activities involving the use of water or the generation of other types of wastewater at W.M. Keck Observatory are entirely contained processes; those wastewaters are captured and stored in sealed containers and hauled off site for treatment and disposal elsewhere.

<u>Surface Runoff from the W.M. Keck Observatory Site</u>. Although the subleased area of the W.M. Keck Observatory site is about 2 ha (5 ac), only about 1.1 ha (2.7 ac) at the top of Pu‘u Hau‘oki have been leveled for the observatory’s use. The remainder of the subleased area consists of the slopes of Pu‘u Hau‘oki. The Keck I and Keck II domes and their connecting structure cover about 0.4 ha (1.0 ac), constituting the impervious surfaces on the leveled portion of the site. The remainder of the leveled area is covered with gravel and sand-sized cinder, both of which have substantial permeability. Although drainage swales may have been installed initially to accommodate runoff and snowmelt from the domes and other impervious surfaces, none remain today. Nonetheless, there is no evidence of erosion by surface runoff anywhere across the leveled area or down the slopes of Pu‘u Hau‘oki. Because the surface cinders are cohesionless and highly erodible, the fact that there is no evidence of surface flow or erosion is significant. It empirically demonstrates that the permeability of the cinder surface exceeds the rates of precipitation at the summit, even during the most severe storms. Consequently, surface runoff does not move across the leveled area or down the slopes.

Each of the six Outrigger Telescopes would have a 9.1-m (30-ft) dome, foundation, junction boxes, and other related facilities. All six would create a total of about 0.05 ha (0.12 ac) of additional impermeable surface on W.M. Keck Observatory’s leveled area, representing a 12 percent increase of the impermeable surfaces at the W.M. Keck Observatory site. Based on the empirical evidence across the leveled area and down the slopes of Pu‘u Hau‘oki cited above, and because the relatively small increase in impervious surface would be at six physically separate sites, generation of surface runoff across the leveled area or down the slopes of Pu‘u Hau‘oki would not occur.

Subsurface Disposal of Domestic Wastewater. The volume of wastewater produced at the W.M. Keck Observatory is not measured. However, it is reasonable to assume that the volume of water trucked to the W.M. Keck Observatory site approximates the volume of domestic wastewater generated there. The amount of water trucked in that is used for other purposes at W.M. Keck Observatory site such as mirror washing is relatively insignificant. Based on delivery records, water trucked to the W.M. Keck Observatory site averages about 45 kl per month (12,000 gal per month) or 1.5 klpd (400 gpd). It is estimated that the Outrigger Telescopes Project would increase this amount by about 9.5 kl per month (2,500 gal per month) or about 0.3 klpd (80 gpd), a 20 percent increase. No new toilets or sinks would be installed for the Outrigger Telescopes. The Outrigger Telescopes are designed as equipment with no habitable spaces for personnel; all staff working on them during operations would use the existing Keck facilities.

Percolating wastewater from the W.M. Keck Observatory's site seepage pit would ultimately reach groundwater beneath the summit or its southwest flanks. This wastewater does not travel to Lake Waiau or to the springs on the west side of Pōhakuloa Gulch for the following reasons:

- Lake Waiau is 1.74 km (1.08 mi) to the south-southwest and 177 m (580 ft) lower than the W.M. Keck Observatory. In the absence of a rather unique and unprecedented subsurface perching layer which extends continuously over this entire distance, a subsurface discharge from the W.M. Keck Observatory site could not move a sufficient distance laterally before dropping more than 177 m (580 ft) in elevation. In other words, if a subsurface discharge did move laterally toward the lake, it would be far below the elevation of the lake by the time it reached there.
- If a unique and unprecedented perching layer with sufficient areal extent and proper elevation and gradient to direct subsurface flow from the W.M. Keck Observatory site toward Lake Waiau actually existed, one or both of the following would occur:
    - Perennial springs would form in the intervening topographic tributaries of Pōhakuloa Gulch in Submillimeter Valley. No such springs exist.
    - Lake Waiau would constantly be overflowing through the low point on the west side of the crater rim, because its contributing watershed, rather than being limited to the confines of the Pu‘u Waiau crater, would be more than 10 times greater (in excess of 162 ha (400 ac)). This is not the case.
- Modeling in Ebel (2001) replicates the historic lake water level data in Woodcock (1980) with the only input to the lake being rain that falls within the crater rim. This is a contributing

watershed area of about 14 ha (35 ac). This modest input still results in overflow on approximately 20 percent of the days over the period modeled. If the contributing area was 10 times greater, continuous overflow would occur.

- The intrusive volcanic structures within the Pu‘u Waiau crater are nearly vertical barriers to perched subsurface water moving into the lake itself.
- The bottom of the lake is lined with thick sediments which are orders of magnitude less permeable than the flow lavas and/or glacial drift through which the percolate would travel. It would be essentially impossible for percolate to move laterally or upward through the sediments against the hydraulic pressure of the water in the lake. The percolate would move laterally around rather than through this poorly permeable obstruction with an adverse hydraulic gradient.
- Because the distance to the springs on the west side of Pōhakuloa Gulch is greater than to Lake Waiau (5.6 versus 1.7 km (3.5 versus 1.1 mi), it is even more unlikely that an aerially extensive and continuous perching layer would extend from Pu‘u Hau‘oki all the way to the springs.
- If an aerially extensive and continuous perching layer were that extensive, the flow at the springs would be far greater and more consistent than their highly variable and quite modest actual discharge.
- Given the trends of topography down the mountain’s south-southwest flank, a perched subsurface flow from Pu‘u Hau‘oki would be much more likely to emerge into Pōhakuloa Gulch rather than into the springs on the west of the gulch. No such discharge occurs.
- Isotopic analyses in Arvidson (2002) show that the water from the springs is similar to the isotopically “light” rainfall that occurs at high elevations near the summit. If wastewater had reached the springs after subsurface discharge at the summit, it would be identifiable by isotopic analysis. Because it originates as water trucked to the summit from sources at a far lower elevation, it would be isotopically “heavier” than the water actually discharged at the springs.

Based on the foregoing analysis, the only potential remaining impact of the W.M. Keck Observatory’s subsurface discharge of wastewater is on the groundwater at depth, which exists thousands of feet below the summit and its flanks. A conservative assessment of this impact can be made with the series of assumptions provided below. Because percolating wastewater from the Observatory site is not likely to move toward the east where groundwater flowrates are very high, the assumptions for this assessment need to be more realistic than the simple dilution calculations made for wastewater percolating from facilities at Hale Pōhaku.

- As with the raw domestic wastewater at Hale Pōhaku, nitrogen and phosphorus concentrations in the W.M. Keck Observatory’s wastewater are assumed to be 40 and 15 mg/l, respectively.
- Nutrient removal rates in the W.M. Keck Observatory’s septic tank and seepage pit system are limited to 20 percent for nitrogen and 10 percent for phosphorus. These removal rates reflect the portion of nutrients that would be captured in the septic tank as

floatable and settled solids. It is assumed that no nutrient removal occurs in the seepage pit.

- Based on the W.M. Keck Observatory's location, wastewater percolating from its seepage pit would move southwest and/or west.
- The wells nearest the southwest or west of the summit are the Waiki'i wells (Nos. 5239-01 and 02 in Table 3-6), 20.3 km (12.6 mi) to the west of the summit. For the purposes of this conservative assessment, it is assumed that all of the wastewater from the septic tank and seepage pit system would travel directly toward the Waiki'i wells.
- The decades-long travel of percolating wastewater from W.M. Keck Observatory's seepage pit to the Waiki'i wells would initially be for thousands of feet of nearly vertical travel through the vadose zone followed by lateral movement in the groundwater for about 19 km (12 mi).
- Nutrient removal rates have been documented for a similar travel path, albeit for a much shorter time and distance. Nance (2002) analyzed the disposal of effluent from the County's Kealakehe Wastewater Treatment Plant for vadose zone travel of just 15 vertical m (50 vertical ft) and a horizontal movement in groundwater of just 1.1 km (0.7 mi), Nance computed removal rates of 83 to 97 percent for nitrogen and 94 to 95 percent for phosphorus. Obviously, removal rates would be much greater for the far longer hypothetical wastewater travel time and distance from the W.M. Keck Observatory site to the Waiki'i wells. However, for this conservative assessment, removal rates of 80 percent for both nitrogen and phosphorus are assumed.

If the Waiki'i wells pump at an average of 0.3 mgd and they capture all of the remaining nutrients in the 480 gpd of the W.M. Keck Observatory's wastewater, their nutrient concentrations would be increased as shown in Table 4-4. The computed increases are 0.4 and 1.6 percent for nitrogen and phosphorus, respectively. Actual increases would be far less than these computed increases, and would have no impact on the quality of water pumped from the wells.

4.1.4 Solid Waste and Hazardous Materials Management

4.1.4.1 ROI for Solid Waste and Hazardous Materials Management

The ROI for solid waste and hazardous materials impacts from the Outrigger Telescopes Project depends upon the material and the manner of release. For example, wind-blown trash could be transported conceivably anywhere across the mountain, while a small spill and clean-up of liquid upon cinder would most likely be confined to the immediate area. For the purposes of this evaluation, considering the types of releases of waste and hazardous materials that have occurred on Mauna Kea in the past, the ROI is defined as the area within the MKSR, a corridor surrounding the Mauna Kea Access Road, Saddle Road, and the potential surface and subsurface water flow paths connected to these areas. Emphasis is placed on the W.M. Keck Observatory site because it is the location of the proposed Outrigger Telescopes Project.

TABLE 4-4. COMPUTED NITROGEN AND PHOSPHORUS INCREASES AT THE WAIKI‘I WELLS

Constituent	Waiki‘i Well Water		W.M. Keck Observatory Effluent Arriving at the Waiki‘i Wells		Combined		
	Flow Rate (gpd)	Concentration (mg/l)	Flow Rate (gpd)	Concentration (mg/l)	Flow Rate (gpd)	Concentration (mg/l)	Percent Increase
Nitrogen	299,520	1.950	480	6.4	300,000	1.957	0.4
Phosphorus	299,520	0.245	480	2.7	300,000	0.249	1.6

4.1.4.2 Impacts of the Outrigger Telescopes Project on Solid Waste and Hazardous Materials Management

Solid Wastes

On-Site Construction and Installation Impacts. On-site construction activity would generate waste debris consisting of wood, scrap insulation, packaging material, waste concrete, and various construction-related wastes. This construction debris would be disposed of in large “roll-off” containers sized to accommodate the debris generated over several days of construction (UH IfA 2001a). No other waste material from the construction process would be disposed of in these roll-off containers. Other wastes, such as liquids, would be collected in leak-proof containers before being removed from the summit.

The construction contractor would remove all construction-related wastes from the summit and take them to an authorized disposal site at least weekly during the construction period (see Appendix F). Given these precautions, no impacts from on-site construction and installation activities are anticipated.

Operation Impacts. Operation of the Outrigger Telescopes would not generate substantially more solid waste than that currently generated by the Keck I and Keck II Telescopes. The existing infrastructure at the observatory would be used to collect the additional trash (UH IfA 2001A).

The W.M. Keck Observatory anticipates that the amount of trash generated by the additional personnel required to operate the Outrigger Telescopes would increase proportionally with the increase in manpower at the summit. The W.M. Keck Observatory anticipates an increase of up to four staff on average for the Outrigger Telescopes, an increase of about 17 percent. Thus the increase in trash generation would be about 0.6 m^3 (0.8 yd^3) per week (CARA 2004h). However, the W.M. Keck Observatory does not expect additional vehicle traffic would be needed to transport additional solid waste from the Outrigger Telescopes more often than the current one to two trips per week (CARA 2004e). As such, no impacts due to solid waste are anticipated from operation activities.

<u>Additional Precautionary Measures</u>. Although no impacts are anticipated from the construction, installation, and operation of the Outrigger Telescopes, additional precautionary measures described in this subsection would reduce the chance of an accidental release of solid waste. The Outrigger Telescopes on-site construction and installation contract(s) would contain provisions regarding the management of solid wastes. Particularly important are

measures to secure solid wastes against dispersal by high winds. Such dispersal could adversely affect plants and Wēkiu bug habitat and degrade the aesthetics of the surrounding area (see Appendices B and F). Examples of such provisions include but are not limited to:

- Construction containers will be equipped with cables to secure the tops and lids to prevent wastes from being blown or dispersed by wind into Wēkiu bug habitat or onto the surrounding slopes of Pu‘u Hau‘oki.
- Construction materials stored at the site will be covered with tarps or anchored in place, and will not be susceptible to movement by wind.
- Outdoor trash receptacles will be secured to the ground, have attached lids and plastic liners, and be collected frequently to prevent predators from foraging for food.
- Construction materials and trash blown into Wēkiu bug habitat or onto the surrounding slopes of Pu‘u Hau‘oki will be collected to the extent practicable, with minimal disturbance to the habitat and cultural properties.

Hazardous Materials

On-Site Construction and Installation Impacts. Some hazardous materials, such as paints, thinners, solvents, and fuel, would be used during the on-site construction and installation of the Outrigger Telescopes. Unused products and spent containers would be collected and transported offsite for proper disposal. Handling of these materials would be guided by a Construction Best Management Practices Plan that would be completed, reviewed, and approved prior to commencement of construction activities. With these measures in place, no impacts from onsite construction and installation activities are anticipated.

Operation Impacts. Operation of the Outrigger Telescopes would require periodic maintenance. The Outrigger Telescopes require fewer maintenance operations than the Keck Telescopes and, accordingly, fewer types and amounts of hazardous materials. With the exception of carbon dioxide, which is present as a compressed gas, no hazardous materials used in the operation of the Outrigger Telescopes would be stored on site. Instead, these materials, which are few in number, would be transported to the summit as needed (CARA 2000b). Once on the summit, hazardous materials used for the Outrigger Telescopes would be controlled by procedures in the CARA Safety Manual. It is not expected that any new materials (i.e. materials not currently used for the Keck Telescopes) would be needed for the Outrigger Telescopes. **No mercury would be used for the Outrigger Telescopes** (CARA 2001d). Given the reduced need for hazardous materials and the management practices in place to handle these materials, no impacts from operation activities are anticipated.

Table 4-5 compares current hazardous materials use for the Keck Telescopes with material required for the Outrigger Telescopes.

The following briefly describes anticipated observatory maintenance activities and operations for the Outrigger Telescopes.

Lubrication of Ball Bearings. During operations, the Outrigger Telescopes would rotate on wheels that contain sealed ball bearings. These bearings require periodic lubrication, which would be accomplished by injecting lubricant directly into the sealed bearing track. Old lubricant would be removed with a rag by simply wiping it from small holes placed along the bearing track.

TABLE 4-5. EFFECT OF OUTRIGGER TELESCOPES ON HAZARDOUS MATERIALS USE AT THE W.M. KECK OBSERVATORY

Material Class	Current Use at the W.M. Keck Observatory	Anticipated Requirements of Outrigger Telescopes
Cooling	Propylene glycol, Keck I, 1.1 kl (300 gal); ethylene glycol, Keck II, 1.1 kl (300 gal); 2.3 kl (600 gal) glycols in storage	No glycol used
Fuel	Diesel 9.5 kl (2,500 gal) in underground storage tank for emergency generator	No fuel required; emergency power provided by existing infrastructure
Hydraulic fluid	Each Keck Telescope uses 2.3 kl (600 gal); 210 l (55 gal) in storage	No hydraulic fluid used
Laser dye	Mixture of ethanol and R2 perchlorates	No laser dye used
Lubricants	Grease used as needed; several 20-1 (5-gal) pails in storage Each Keck Telescope uses 1.9 kl (500 gal); 0.4 kl (100 gal) in storage	Gear oil (66 l per Outrigger Telescope) and grease used; no additional lubricants stored on site
Mercury	5.8 kg (13 lb) in use, 7.7 kg (17 lb) in storage	No mercury used
Mirror decoating, recoating, and maintenance	Up to 4 mirrors (of 78) recoated each month; hydrochloric acid, 20 l (5 gal) in storage; potassium hydroxide, 2 kg (4 lb) in storage; copper sulfate, 1.4 kg (3 lb) in storage; hydrofluoric acid, several centiliters (several ounces) in storage	Up to six mirrors decoated with hydrochloric acid every 2 years; no additional chemicals stored on site
Other compressed gases	Carbon dioxide used for snow cleaning, two 8.6-kl (300 ft^3) bottles used each month; helium, nitrogen, oxygen, acetylene in use	Carbon dioxide used for snow cleaning monthly; 8.6-kl (300-ft^3) bottle stored in each Outrigger Telescope
Paints and related solvents	Various amounts stored on site	Used as needed; no additional paint and solvents stored on site

The rags and grease along with similar wastes from the Keck Telescopes would be disposed by a licensed disposal contractor (UH IfA 2001a).

Mirror Recoating. The Outrigger Telescope primary mirrors would require recoating in the same manner as the mirror segments for the Keck Telescopes. Thus, there would be an addition of four, and possibly up to six, Outrigger Telescope mirrors to the existing 78 Keck Telescope mirror segments that would require periodic recoating. The six Outrigger Telescope mirrors would increase the total number of mirrors requiring recoating by less than 8 percent. The W.M. Keck Observatory could wash the Outrigger Telescope mirrors once a year using a soap and water solution (no hazardous chemicals) and only re-aluminize them every 2 to 3 years at the same interval for recoating the Keck mirror segments (CARA 2001d).

The Outrigger Telescope secondary and tertiary mirrors would not require periodic recoating (CARA 2004e). The Outrigger Telescopes would contain smaller optics in the interferometer ranging in size from very small (25 millimeters (1 in (in)) to 0.5 m (1.6 ft)). The smaller optics would require periodic recoating, but because they are located in a more protected environment, recoating would only be necessary approximately every 4 years. The smaller optics could have silver or gold coatings. The W.M. Keck Observatory has not decided whether to recoat these optics on site or to send them out for recoating (CARA 2000d).

The procedure for removing the old aluminum coating on Outrigger Telescope mirrors and applying a new one would be the same as described previously for the Keck Telescope mirror segments. The active ingredients in the aluminum removal solutions would also be the same. The rinse water from the aluminum removal process would be collected and transported off the site.

The Outrigger Telescopes primary, secondary, and tertiary mirrors would require spray cleaning with carbon dioxide on a monthly basis, the same frequency as described for the Keck Telescopes. The W.M. Keck Observatory would store one 8.6-kl (305-ft^3) bottle in each Outrigger Telescope. It is anticipated that each bottle would last for more than 6 months (CARA 2004f).

Other Operations and Maintenance. The W.M. Keck Observatory would not use glycol or hydraulic fluid in the Outrigger Telescopes (CARA 2004e). The W.M. Keck Observatory would use 66 l (17.5 gal) of gear oil and 1 l (1 qt) of grease per Outrigger Telescope.

Additional Precautionary Measures. All on-site construction and installation contract(s) would contain provisions regarding the management of hazardous materials (see Appendix F). Even though there is no impact resulting from the handling of solid waste and hazardous materials, the following additional precautionary measures will be taken.

Such provisions include but are not limited to the following:

- Only the amount of hazardous materials that will be used for a particular activity will be transported to the W.M. Keck Observatory
- The contractor would maintain a log of all hazardous materials brought up to the summit. This log would be available for inspection by the CARA Safety Officer.
- Painting equipment would be cleaned off site to reduce the risk of a spill (CARA 2004d).
- Equipment will be refueled on site from a refueling truck (CARA 2004a). To minimize the potential for a fuel spill, no equipment fuel tank would be filled to the top.

4.1.5 Geology, Soils, and Slope Stability

4.1.5.1 ROI for Geology, Soils, and Slope Stability

The ROI for assessing the potential impacts from implementing the Outrigger Telescopes on geology, soils, and slope stability would be the summit of Mauna Kea and areas near Hale Pōhaku where construction staging and laydown activities would take place.

4.1.5.2 Impacts of the Outrigger Telescopes Project on Geology, Soils, and Slope Stability

On-Site Construction and Installation Impacts. There would be only small and not significant impacts during the construction phase of the Outrigger Telescopes. Materials excavated for foundations and connecting conduits for the Outrigger Telescopes would be removed for use elsewhere, and would not be deposited over the sides of the cones. Because Outrigger Telescopes 3 and 4 are to be built close to the steep edges of Puʻu Hauʻoki, retaining walls would be built at the upper edges of these slopes so that excavated cinders and debris do not cascade downslope during construction. This would also prevent foot traffic from degrading the slope edge following construction. Excavated material will be used as backfill to cover light pipes and airpipes, and to provide screened and washed cinder for Wēkiu bug habitat restoration.

A temporary silt fence will be installed along the crater rim to facilitate on-site containment of all material, including cinder, so that no material spills over the slope. A silt fence will be used whenever excavation occurs within 1.8 m (6 ft) of the slope.

The CARA Construction Manager and the on-site construction and installation contractor(s) will prepare a Construction Best Management Practices Plan (BMP) in consultation and coordination with OMKM and UH. The BMP will be finalized prior to the start of construction. This BMP will reference the MOA and include it as an appendix.

Operation Impacts. There would be no impacts during the operations phase of the Outrigger Telescopes.

Additional Precautionary Measures. Even though impact on soils, slope stability, and geology would be small and not significant, the following additional precautionary measure will be taken.

- All excavated material not necessary for backfill or Wēkiu bug habitat restoration will be transferred to other locations accessible from the established roads on the summit of Mauna Kea. These locations will be identified in consultation with the Hawaiʻi SHPO and OMKM prior to the start of construction.

4.1.6 Land Use and Existing Activities

4.1.6.1 ROI for Land Use and Existing Activities

Land use refers to the use permitted by the State Land Use Commission within a particular State Land Use District. Existing activities refer to the types of physical activities that occur within a designated area (e.g., hiking, sightseeing, scientific research).

Impacts on land use were based on whether project activities would be consistent with State and local plans and on whether land uses would be compatible with State land use designations. Impacts on existing activities were assessed by identifying the activities that occur within the ROI and evaluating whether the Outrigger Telescopes Project would have any short- or long-term effects on them.

The ROI for assessing land use impacts includes the MKSR and Hale Pōhaku. The ROI for assessing existing activities impacts includes the MKSR and other areas affected by on-site construction, installation, and operations; these include the Mauna Kea Natural Area Reserve, Hale Pōhaku, and vehicle travel routes.

4.1.6.2 Impacts of the Outrigger Telescopes Project on Land Use and Existing Activities

Land Use

On-Site Construction and Installation Impacts. The MKSR is contained entirely within the Resource Subzone of the Conservation District. On-site construction and installation of the Outrigger Telescopes would be consistent with uses permitted in the Resource Subzone (see Section 3.1.1). In addition, the proposal to locate the Outrigger Telescopes in the Astronomy Precinct is consistent with the recently adopted 2000 MKSR Master Plan (UH 2000b), which designates the MKSR as a multi-use resource, and currently supports a variety of scientific, cultural, and recreational uses (UH 2000b). Furthermore, the Outrigger Telescopes would lie within the area of the MKSR designated for astronomy activities and would be consistent with that use.

Support activities at Hale Pōhaku connected to the Outrigger Telescopes Project would also be consistent with current land uses. In conclusion, there would be no land use impact associated with this phase of the Outrigger Telescopes Project.

A Coastal Zone Management Act compatibility determination does not apply to NASA's proposal to fund the Outrigger Telescopes on Mauna Kea (DBEDT 2004).

Operation Impacts. The operation of the Outrigger Telescopes would be consistent with the current designated land use. There would be no land use impact associated with this phase of the Outrigger Telescopes Project.

Existing Activities

On-Site Construction and Installation Impacts. Activities associated with the on-site construction and installation of the Outrigger Telescopes Project would occasionally delay traffic along the Mauna Kea Access Road and temporarily increase noise levels. See sections related to transportation (Section 4.1.7) and noise (Section 4.1.11) impacts for additional information. It is also anticipated that the viewscape of the proposed site and construction staging areas at the summit and Hale Pōhaku would be temporarily impacted by the presence of large construction equipment, materials, and telescope components. See Section 4.1.12 for more information regarding visual impacts.

Although some transportation, noise, and visual impacts would occur, it is anticipated that the Outrigger Telescopes Project would not result in a long-term conflict with or have a substantial impact on existing activities in the ROI. The ability to use the land within the ROI for cultural and religious practices, astronomical and other scientific research, and a variety of recreational activities would remain consistent with the current use. In conclusion, all construction and installation activities on Mauna Kea would be conducted in a manner that would allow the surrounding area to remain accessible for all existing activities. See Section 4.1.1 for a detailed discussion of cultural and religious impacts.

Operations Impacts. All telescope and facility operations associated with the Outrigger Telescopes Project would be conducted in a manner that would preserve access to the surrounding area for all existing activities. The only continuing impact of the Outrigger Telescopes operations on existing activities would be the visual presence of the telescope enclosures. However, because the Outrigger Telescopes would be located next to the much larger Keck I and II structures, their impact would be a small increment to the impact that has already occurred.

Mitigation Measures. Refer to the following sections of this chapter for mitigation measures associated with transportation (Section 4.1.7), noise (Section 4.1.11), and visual impacts (Section 4.1.12).

4.1.7 Transportation

4.1.7.1 ROI for Transportation

The ROI for assessing transportation impacts from the Outrigger Telescopes Project includes the MKSR and other areas affected by on-site construction, installation, and operations including Hale Pōhaku and vehicle travel routes.

Transportation refers to the movement of vehicles along roads. This section addresses the impact of short- and long-term traffic levels on the local traffic network and its effect on the natural setting of Mauna Kea.

4.1.7.2 Impacts of the Outrigger Telescopes Project on Transportation

On-Site Construction and Installation Impacts. An estimated 15 construction workers would be on the project site during the first 24 months; an additional 15 workers would overlap the construction work during the last 5 months to assemble the domes and install the telescopes. It is assumed that each worker would have a light-duty, gasoline-fueled vehicle traveling to the site from an off-mountain location 5 days a week (approximately 120 km (75 mi) per day). In addition, as described in Section 4.1.1, it is assumed that a cultural monitor and an archaeologist would travel daily from off-mountain to the summit. Four heavy-duty diesel trucks (cement, water, flatbed trucks, etc) would make 1,000 round trips over the life of the project traveling approximately 120 km (75 mi) per day. Other equipment would remain on site at Hale Pōhaku and would travel from there to the summit (approximately 13.4 km (8.3 mi)) as needed. At any one time as many as six container loads of dome enclosures and/or telescope components would travel from the harbor at either Kawaihae or Hilo to the summit area, and would be off-loaded at the staging area and delivered to the W.M. Keck Observatory for assembly.

Vehicular traffic would occasionally delay traffic along the Mauna Kea Access Road. The greatest traffic delays would occur when the telescopes and domes are trucked up the mountain. This traffic would occur only intermittently and thus should not regularly interfere with normal traffic flow. While construction vehicles are slow and difficult to maneuver, they would not have any long-term impact on either the road or overall traffic flow.

Construction traffic within the ROI would create minor short-term increases in dust and emissions and temporarily increase noise levels. See Section 4.1.10 for impacts associated with air quality and Section 4.1.11 for information on noise impacts.

It is also anticipated that the current viewscape of the proposed site and construction staging areas at the summit and Hale Pōhaku would be temporarily impacted by the presence of large construction vehicles. See Section 4.1.12 for more information regarding visual impacts. Overall, this project phase would result in short-term minor impacts.

Transportation of minimal quantities of hazardous materials (e.g., diesel fuel, motor oil, paints, and solvents) and wastes would be expected throughout the construction and installation phases of the Outrigger Telescopes Project (see Section 4.1.4). Handling these materials would be guided by a Construction Best Management

Practices Plan. No impact would be expected.

Operation Impacts. An estimated two to three roundtrips per day and about one roundtrip per night along the Mauna Kea Access Road would be required during the operations phase of the Outrigger Telescopes Project (UH IfA 2002b). The number of trips by service vehicles, such as water and fuel trucks, would not be expected to increase (UH IfA 2001a). In conclusion, this slight increase in traffic associated with this project phase would create a very small impact on transportation.

Mitigation Measures. Trips by heavy trucks will be scheduled during off-peak hours to avoid interfering with normal traffic flow in Kawaihae, Waimea, or along the Saddle Road. In addition, CARA will coordinate with other road users to avoid traffic problems when non-standard-sized loads are transported from the staging areas to the W.M. Keck Observatory.

4.1.8 Utilities and Services

4.1.8.1 ROI for Utilities and Services

The ROI for assessing utilities and services impacts of the Outrigger Telescopes Project includes the W.M. Keck Observatory, the MKSR, Hale Pōhaku, and vehicle travel routes.

This section addresses potential impacts on water supply, electrical supply and communications, and emergency services and fire suppression.

4.1.8.2 Impacts of the Outrigger Telescopes Project on Utilities and Services

Water Supply

<u>On-Site Construction and Installation Impacts</u>. On-site construction of four, and possibly up to six, Outrigger Telescopes would result in an increase in the demand for potable water due to the increased number of workers at the site and the implementation of dust controls and cinder washing (see Section 4.1.3.2). The construction contractor(s) would transport this additional water to the summit area. Therefore, there would be no impact on the existing water supply at the W.M. Keck Observatory site.

<u>Operation Impacts</u>. Current water consumption at the W.M. Keck Observatory site is typically 11 kl (3,000 gal) per week for all purposes (UH IfA 2001a). Operational support at the summit would not require additional water tanker trips nor would it impact the Island's water supply (UH IfA 2001a).

Electrical Power and Communications

<u>On-Site Construction and Installation Impacts</u>. On-site generators provided by the construction contractor would provide power. Electrical generators would be staged on site to provide additional electrical power for equipment during construction and installation. Only a minor increase in demand for electrical power on the summit distribution system would occur during this period. This increase would have no impact on the existing electrical supply system.

<u>Operation Impacts</u>. The electrical power requirement for each Outrigger Telescope is estimated to be 30 kilowatts (kW) (UH IfA 2001a). Peak demand load at the Hale Pōhaku substation for all facilities on the summit (including Keck I and Keck II) is currently approximately 2,230 kW. Peak electrical demand at the W.M. Keck Observatory site is currently 525 kW; operation of the Outrigger Telescopes would increase this demand by about 34 percent to 705 kW (CARA 2004i). Peak electrical power usage at W.M. Keck Observatory, with the two Keck Telescopes and the six

Outrigger Telescopes in operation, would be about 70 percent of its existing 1,000-kW capacity (CARA 2004i). The Hale Pōhaku substation has the electric power capacity to accommodate the additional operation of all six Outrigger Telescopes.

In conclusion, the addition of four, and possibly up to six, Outrigger Telescopes would have no impact on the electrical supply system at the W.M. Keck Observatory site.

The existing communications system for Keck I and Keck II has adequate capacity to accommodate the addition of the Outrigger Telescopes. Additional fiber optic cable systems would be installed to link the Keck Telescopes and the Outrigger Telescopes into a functionally integrated system. These activities would have no impact on the existing system.

Emergency Services and Fire Suppression

On-Site Construction and Installation Impacts. The need for emergency services is related to the number of personnel at the summit and the types of work or activities they perform. As stated already approximately 15 construction workers would be on the project site during the first 24 months; an additional 15 would overlap the construction work during the last 5 months to assemble the domes and install the telescopes.

The construction contractor would have the primary responsibility of ensuring worker safety. In the event of an injury or accident, the existing emergency preparedness plan and evacuation equipment and procedures that apply to the W.M. Keck Observatory and all observatories at the summit would be adequate to provide treatment on-site or evacuation off the summit. No additional equipment or personnel or modification of emergency procedures are anticipated during on-site construction. There would be no impact associated with this phase of the Outrigger Telescopes Project.

Operation Impacts. It is estimated that four personnel would be required for testing the Outrigger Telescopes and four more when operations begin. Existing emergency services and procedures would be adequate to accommodate this small increase in personnel.

The Outrigger Telescopes would include fire alarm systems and suppression equipment similar to those in use at Keck I and Keck II. No special fire suppression or response equipment or procedures would be required for operation of the Outrigger Telescopes. The additional personnel would follow established procedures and would be included in existing W.M. Keck Observatory fire drills and annual fire safety training. There would be no impact associated with this phase of the Outrigger Telescopes Project.

4.1.9 Socioeconomics

4.1.9.1 ROI for Socioeconomics

The ROI for assessing socioeconomic impacts would primarily be the MKSR and communities where construction staff and astronomers reside.

4.1.9.2 Impacts of the Outrigger Telescopes Project on Socioeconomics

On-Site Construction and Installation Impacts. It is anticipated that Construction workers would either commute from sea level or reside in at the Hale Pōhaku construction camp.

The cost for on-site construction and installation of four Outrigger Telescopes and domes is estimated at $10 million. The cost for on-site construction and installation of the remaining two Outrigger Telescopes would probably be between $2.5 and $3 million. The total construction and installation cost of all six Outrigger Telescopes and domes would be about $13 million; a 2 percent increase in capital expenditures over that required for the existing Mauna Kea observatories (see Table 3-11). The addition of approximately 35 jobs (construction crews, archaeologist, cultural monitor, etc.) would temporarily increase the staff of the Mauna Kea observatories by about 7 percent. This construction spending and job growth would have a positive impact on the community.

Operation Impacts. NASA would also fund the Outrigger Telescopes operation. It is estimated that a total of eight full-time personnel would be added to the W.M. Keck Observatory staff; four would be hired when testing of the Keck Interferometric Array begins and four more when operations begin. In addition, there could be several new technicians who would work on the summit. Overall, the daytime presence at the summit would be increased by a maximum of seven people; The Outrigger Telescopes operations would increase the current operating budget of the W.M. Keck Observatory by $5 to $7 million a year. This represents an 11 percent increase in the total operating costs of the Mauna Kea observatories. Economic benefits would flow primarily to the Hilo and Waimea communities in the County of Hawaii. In summary, the Outrigger Telescopes Project would have a small positive socioeconomic impact on the County and State of Hawai‘i.

<u>Commercial Activities</u>. The addition of the Outrigger Telescopes at the W.M. Keck Observatory is not expected to produce any substantial increase in commercial tour traffic or similar activities.

4.1.10 Air Quality

4.1.10.1 ROI for Air Quality

The direct emissions ROI is considered to be the area around the Astronomy Precinct, a corridor surrounding the Mauna Kea Access Road and Saddle Road. Dust or equipment emissions from construction within the Astronomy Precinct or from traffic along the unpaved or paved roadways could impact air quality.

4.1.10.2 Impacts of the Outrigger Telescopes Project on Air Quality

On-Site Construction and Installation Impacts. On-site construction and installation of the Outrigger Telescopes and dome enclosures would result in short, small, but measurable, levels of air pollution. Dames & Moore analyzed the air quality impacts from on-site construction of the Outrigger Telescopes (Dames & Moore 1999b). Their findings are summarized below.

Short-term on-site construction effects would come from construction equipment and vehicles exhaust emissions, and fugitive dust emissions from earthmoving activities and vehicle travel on unpaved roadways.

In addition, portable electrical generators which produce exhaust emissions would be used to provide additional electrical power during construction and installation.

Emissions associated with construction activities would be short term and would end with the completion of on-site construction. Strict compliance by the construction contractor with the State Department of Health (DOH) Administrative Rules and the County of Hawai’i grading permit would minimize the short-term effects on air quality.

Air emissions receptors could include humans, flora and fauna, and observatory equipment and optics sensitive to dust concentrations. Cultural practitioners, construction workers, scientists, staff, and visitors to the area could potentially be affected.

Fugitive dust would result from the excavation of approximately 918 cubic meters (m^3) (1,200 cubic yards (yd^3)) of cinder to install about 274 m (900 ft) of light pipe and air pipe trenches and approximately 1,835 m^3 (2,400 yd^3) of cinder from excavation for telescope footings, dome foundations, and light tunnels.

Earthmoving activities would generate dust amounts that can be estimated based on the amount of area disturbed and the period of construction. As stated previously, underground site work for four, and possibly up to six, Outrigger Telescopes would require an estimated 15 construction workers on the project site during the first 24 months; an additional 15 construction workers would overlap during the last 5 months to assemble the dome enclosures and install the telescopes. Installation of the remaining two Outrigger Telescopes, if funded, would likely begin no earlier than 2007.

The Environmental Protection Agency's (EPA) recommended methodology (AP-42 Section 13.2.3 (USEPA 1995)) was used to estimate fugitive dust emissions using available construction equipment information (Dames & Moore 1999b) and soil data (HLA 1991). This analysis updated information on the potential equipment needs for the Outrigger Telescopes Project and used a revised installation schedule.

The fugitive dust emissions of particulate matter (PM_{10}) from the Proposed Action are estimated to be 1.40 metric tons (1.54 tons) or less for the peak construction year. This estimate does not take into account planned mitigation measures.

Table 4-6 summarizes the estimated maximum construction air pollutant emissions calculated and presented in the Dames & Moore analysis. This analysis used conservative assumptions. Each worker was assumed to drive a private, light-duty, gasoline-fueled vehicle to the summit work site, 120 km (75 mi) per day from Hilo or Waimea. This is a conservative assumption, because workers would likely carpool, and some workers would remain at Hale Pōhaku during the workweek. It was further assumed that four heavy-duty, diesel trucks (cement, water, flatbed trucks, etc.) would make 1,000 trips over the life of the project. Other equipment would remain on site and would be used according to the schedule presented in the report (Dames & Moore 1999b). Data about emissions from equipment operated more than 9 months of the year in the Dames & Moore report (Dames & Moore 1999b) were reduced proportionately to account for the on-site construction and installation schedule. Other equipment not considered in the Dames & Moore report was added using the same references as were used in the Dames & Moore report. Representative types of equipment were selected for the analysis and the total usage was estimated (Dames & Moore 1999b).

Carbon monoxide (CO) and nitrogen oxide (NO_x) emissions would be expected from on-site construction equipment and from construction workers vehicles and motorized construction equipment traveling to and from the summit. Much of the vehicular emissions of CO and volatile organic compounds would be emitted over the approximately 120 km (75 mi) of roadways between the Mauna Kea summit area and locations such as Hilo and Waimea, with much of this occurring below the typical

TABLE 4-6. SUMMARY OF THE ESTIMATED MAXIMUM CONSTRUCTION AIR POLLUTANT EMISSIONS (IN TONS PER YEAR)

Sources	Carbon Monoxide (CO)	Volatile Organic Compounds (VOC)	Nitrogen Oxides (NO_x)	Sulfur Oxides (SO_x)	Particulate Matter (PM_{10})
Fugitive dust emissions	—	—	—	—	1.54
Equipment emissions	0.15	0.04	0.29	0.03	0.04
Vehicular emissions	19.65	2.25	2.34	Negligible	Negligible
Total	19.81	2.29	2.63	0.03	1.58
Significance threshold	250	250	250	250	250

Note: Updated using EPA AP-42 Volume I for Fugitive Emissions and Volume II for Equipment and Vehicular Emissions.

inversion layer altitude of about 2,134 m (7,000 ft). The construction emissions would therefore largely have regional impact rather than a site-specific impact. The estimated emissions of all pollutants, including localized fugitive dust emissions, are anticipated to be well below the significance levels of 250 tons per year for suspended particulate and combustion emissions (Dames & Moore 1999b).

Installation of the Outrigger Telescopes primarily involves transporting the telescope dome enclosures and telescopes to the W.M. Keck Observatory site by flatbed trucks. The expected emissions from these activities, including localized fugitive dust and exhaust emissions from the trucks, would remain below the significance threshold for particulate and combustion emissions.

Summit wind velocity usually ranges between 16 and 24 km (10 and 15 mi) per hour, with speeds exceeding 160 km (100 mi) per hour during severe storms (Dames & Moore 1999b). Dust ash and cinder disturbed during excavation could be carried by these winds and deposited on adjacent slopes. Construction would be halted during storms. For purposes of estimating fugitive emissions, an average wind speed of 25 km (15 mi) per hour was assumed. It is possible that excessive dust could impact Wēkiu and their habitat as well as existing telescope mirrors and other sensitive equipment. Dust control at the Observatory site would therefore be imperative. Dust control mitigation measures are described below.

In summary, there would be a small impact on air quality from this phase of the project.

Operation Impacts. Air quality at the Astronomy Precinct and Hale Pōhaku would return to existing conditions once the Outrigger Telescopes Project on-site construction and installation is completed. A slight increase in vehicular traffic and emissions would likely result from scientists and Outrigger Telescopes Project staff traveling on the unpaved section (roughly 7.2 km (4.5 mi)) of the roadway from Hale Pōhaku to the project site. Overall air quality at Mauna Kea would remain very good because of low intensity of use and the substantial winds in effect most of the time. The operation of the Outrigger Telescopes would have no impact on air quality in and around Mauna Kea.

Mitigation Measures. CARA has made a commitment to NASA that the following mitigation measures would be implemented and made part of any construction contracts.

These measures have been included in the NHPA Section 106 MOA found in Appendix B and in the Construction Best Management Practices Plan in Appendix F.

Dust Controls. The following dust control measures will be therefore implemented.

- Potable water will be applied to excavation sites and cinder stockpiles to minimize dust during trenching, bulldozing or other soil disturbance activities. This water would be transported to the site and applied as needed during. It would not be expected to cause any negative impact to the Wēkiu bug; it is possible that application of water to excavation sites could increase the amount of moisture available for Wēkiu bugs.
- Dust generation will be minimized during construction to the extent practicable by water suppression. Only small or contained areas will be affected at any given time.
- Dust-generating activities will be suspended during periods of high winds, and water would be applied to recently exposed cinder and ash to minimize dust.
- Environmentally safe soil stabilizers will be used to reduce dust during and after on-site construction on roads and parking areas when application of potable water is inadequate for dust control.
- Environmentally safe soil stabilizers will be applied under light wind conditions to prevent cinder dust from drifting into Wēkiu bug habitat. Products considered for use will be reviewed by an entomologist knowledgeable of Wēkiu bug ecology before being considered for use.
- Cinder or ash will be moved to temporary stockpile areas and, if necessary, covered with tarps that are tied down. Permanent placement of excavated cinder fill and ash from the project area elsewhere on Mauna Kea during on-site construction will be determined in consultation with the SHPD and the OMKM.

Other mitigation measures will include requiring contractors to minimize combustion emissions by maintaining construction vehicles and equipment properly. Engine emissions will be controlled by the use of functional emission devices as required by law. Equipment idling will be kept to a minimum. Contractor compliance with dust control mitigation measures will be monitored as described in the Wēkiu Bug Monitoring Plan, Section 2.5 (see Appendix E).

4.1.11 Noise

4.1.11.1 ROI for Noise

The ROI for assessing noise impacts from the Outrigger Telescopes Project includes the MKSR and other areas affected by on-site construction, installation, and operations including Hale Pōhaku and vehicle travel routes.

The noise-sensitive receptors within the ROI include cultural practitioners, scientists, staff, recreational users, and other visitors. There are no fixed noise-sensitive receptors, such as residential areas, within the ROI. Noise impacts are inherently localized as noise levels decrease non-linearly with increasing distance from the source.

4.1.11.2 Impacts of the Outrigger Telescopes Project on Noise

On-Site Construction and Installation Impacts. Noise would result from excavation, trenching, grading, installation of sheet piling for utility protection, installation of junction boxes, construction of light and air pipes, construction of telescope dome foundations, and installation of telescopes and domes.

Actual noise levels would depend upon the mix and duration of construction equipment and methods used. The vibrating hammer used to install sheet piling, would most likely be the loudest piece of equipment used during construction (approximately 95 A-weighted decibels (dBA) at 15 m (50 ft)). It is anticipated that the use of this equipment would be short-term, lasting 1 or 2 days. Short-term noise impacts will be minimized through the use of construction equipment and vehicles with proper noise muffling devices. No blasting would occur during the construction process. Noise from these activities would be inaudible at times at a relatively short distance from the source because of the existing background noise associated with the strong wind conditions at the summit.

Transport of materials and equipment and daily construction traffic would also create noise. Increased noise levels would occur intermittently along routes used by construction and operation equipment. On average, construction worker traffic is expected to add 15 trips in the morning and evening (UH IfA 2002b). Most heavy construction equipment would be stored on site during the construction period. See Section 4.1.7 for additional transportation information. It is anticipated that individuals at Hale Pōhaku and near the Mauna Kea Access Road could hear noise from increased vehicular traffic.

This intermittent, short-term noise could result in minor disturbances to scientists, staff, recreational users, and other visitors within the ROI. In addition, a noise level increase could affect cultural and religious practices. However, any noise disturbances or interruptions would end once on-site construction and installation is completed. Therefore, moderate noise impacts would be associated with this project phase.

Operation Impacts. Operation of the Outrigger Telescopes would result in a negligible increase in noise and a minor increase in vehicular traffic noise at Hale Pōhaku and along the Mauna Kea Access Road. See Section 4.1.7 for additional vehicular traffic information. In conclusion, there would be no impact associated with this phase of the Outrigger Telescopes Project.

Mitigation Measures. Any noise impacts on construction workers will be mitigated by adherence to appropriate Occupational Safety and Health Administration standards. Construction contractor(s) will be required to strictly comply with Hawaii Administrative Rule, Title II, Chapter 46, Community Noise Control. See Section IV of the Construction Best Management Practices Plan (BMP) in Appendix F.

4.1.12 Visual/Aesthetics

4.1.12.1 ROI for Visual/Aesthetics

The ROI for visual impacts is primarily the MKSR and any other area from which the W.M. Keck Observatory would be visible, including, but not limited to, Waimea and Honoka'a.

4.1.12.2 Impacts of the Outrigger Telescopes Project on Visual/Aesthetics

On-Site Construction and Installation Impacts. Any impacts to the view planes associated with on-site construction and installation of the Outrigger Telescopes Project would be temporary and short term. These impacts would stem from the transport of construction equipment and machinery up to Hale Pōhaku and to the

W.M. Keck Observatory site, and the minor additional vehicular traffic transporting the workforce to the work sites. Construction activities and machinery at the W.M. Keck Observatory site would be visible from most locations within the Astronomy Precinct. These activities and machinery would also generally be visible from off-mountain locations to the north and west of the summit such as Waimea and Honoka'a.

The use of dust control measures during construction will substantially mitigate this potentially visible evidence of construction activity.

Operation Impacts. The Outrigger Telescopes would be visible from most locations within the Astronomy Precinct. However, they would not be visible from the true summit, and one or more Outriggers would generally be obscured by the Keck Telescope domes.

Below the summit area, the mountain topography would determine visual impacts from the Outrigger Telescopes. The Outriggers would generally be visible from off-mountain locations to the north and west of the summit such as Waimea and Honoka'a. They would not be visible from locations to the east and south such as Hilo and the Saddle Road (see Figure 3-14). Where visible, the Outrigger Telescopes' visual impact would be small compared to the impact of the much larger Keck Telescope domes.

CARA has designed the dome ring walls to blend into the natural color of the surrounding weathered cinder. This is compliant with mitigation measures set forth in the 2000 MKSR Master Plan (UH 2000b) and the Section 106 MOA (see Appendix B).

In summary, the Outrigger Telescopes would have a small impact on Visual/Aesthetics.

4.1.13 Environmental Justice

Executive Order 12898 and the companion Presidential Memorandum signed February 11, 1994, direct Federal agencies to include in their NEPA documents an analysis of the human health and environmental effects of their actions on minority and low-income communities, and where appropriate, develop mitigation measures to reduce or avoid significant and adverse effects.

Evaluation of the environmental impacts of on-site construction, installation, and operation of the Outrigger Telescopes Project in Section 4.1 of this Draft EIS has indicated that these impacts would range from very small to negligible. Because there are no substantial human populations in the vicinity of the proposed project, these impacts would not result in any pollutant emission level that would potentially adversely impact human health.

Therefore, on-site construction, installation, and operation of the Outrigger Telescopes at the W.M. Keck Observatory would not have disproportionately high or adverse human health or environmental effects on low-income or minority populations. However, NASA recognizes the special cultural and spiritual significance of Mauna Kea to members of the Native Hawaiian community. See Section 4.1.1 for a discussion of the cultural resource impacts.

Mitigation Measures. See Chapter 5 for a summary of measures that would be implemented to mitigate cultural resource impacts.

4.1.14 Adverse Environmental Impacts That Cannot Be Avoided

Adverse impacts are divided into short- and long-term effects. Short-term effects are generally associated with construction and last only during the construction period. Long-term effects generally follow completion of the improvements and are permanent. Adverse and unavoidable short- and long-term effects are described below:

4.1.14.1 Unavoidable Adverse Short-Term Effects

- Operation of construction equipment, trucks, and worker vehicles would temporarily impede traffic along the public roads serving Mauna Kea during the construction period. This minor impact would be intermittent and temporary and would cease once construction is completed. The transport of large machinery and large Outrigger Telescope components could temporarily impede traffic flow and result in temporary traffic delays on the highway serving Mauna Kea, the Mauna Kea Access Road, and the road to the summit. These impacts would be limited to a very brief period at the beginning and end of the construction period.
- Increased vehicular traffic and internal combustion engines on heavy equipment would generate emissions. These emissions would be localized and would not impact the overall air quality on the island of Hawaiʻi. Emissions from construction-related vehicles and equipment would cease once construction is completed.
- Heavy construction equipment operations on site and increased traffic along the access road would lead to temporary generation of small dust particles. Although daily mitigation measures would be taken to significantly reduce these impacts, some soil would occasionally be subject to erosion during periods of high winds.
- Heavy construction equipment operations on site and the transport of large machinery along the public roads serving Mauna Kea would lead to intermittent and temporary increases in noise levels. This transport would occur during a very brief period at the beginning and end of the construction period.
- Construction equipment, related materials, and temporary structures located on site during the construction phase of the project would affect the visual quality of the area for some viewers. Any changes to the visual quality of the area would be temporary because all equipment and excess materials would be removed at completion of construction.

4.1.14.2 Unavoidable Adverse Long-Term Effects

- As indicated during the scoping for this EIS, the presence of the Outrigger Telescopes would adversely impact the visual quality of the summit area for some of the people using the mountain, particularly many Native Hawaiians.
- In addition, many Native Hawaiians believe the Outrigger Telescopes would add to the observatories' already adverse impacts on cultural values related to the mountain.

> *"When an agency is evaluating reasonably foreseeable significant adverse effects on the human environment in an environmental impact statement and there is incomplete or unavailable information, the agency shall always make clear that such information is lacking."*
>
> *40 CFR 1502.22*

- The small additional workforce necessary for operation of the Outrigger Telescopes would result in a small increase in wastewater at the Keck Observatory. While this is not anticipated to have an adverse environmental impact, many Native Hawaiians view this as an adverse impact on the cultural values associated with Mauna Kea.

- Workforce traffic associated with the Outrigger Telescopes would result in very minor increases in noise levels along the public roads serving Mauna Kea, including the Saddle Road and the Mauna Kea Access Road.
- On-site construction and installation of the Outrigger Telescopes would disturb a small portion of Wēkiu bug habitat that was previously disturbed by Keck Observatory construction (see Section 4.1.3). However Wēkiu bug habitat would be restored at a ratio of at least 3:1.

4.1.15 Incomplete or Unavailable Information

Detailed project plans are not yet available for reasonably foreseeable future activities. In the absence of this information, the cumulative impact analysis has been carried out under a set of conservative assumptions.

Although knowledge of Wēkiu bug ecology and population dynamics is incomplete, existing information indicates that implementation of the Outrigger Telescopes Project would not have substantial adverse impacts on the Wēkiu bug or its habitat. Because the Outrigger Telescopes Project would disturb a very small amount of previously disturbed habitat at the margins of the already developed Keck Observatory site, the Project has committed to implementation of a Wēkiu Bug Mitigation Plan during on-site construction and installation, continuing into facility operation. Key elements of the Plan are restoration of Wēkiu bug habitat along the slopes of Puʻu Hauʻoki and in the crater bottom, monitoring the effectiveness of the restoration, and conducting additional studies of Wēkiu bug ecology. Thus, the Outrigger Telescopes Project would contribute substantially to the knowledge base of this rare species of Hawaiian biota.

4.1.16 Relationship between Short-Term Uses of the Human Environment and Maintenance and Enhancement of Long-Term Productivity

The proposed project would be an important addition to Hawaiʻi's growing research and development industry, which can provide broadened employment opportunities for State residents. The productivity of Mauna Kea's summit region, however, cannot be measured in purely traditional economic terms. Mauna Kea is a natural and scientific resource that belongs to all State residents and future generations. A goal of the 2000 MKSR Master Plan is to integrate and balance cultural, natural, education/research, and recreational values and uses in a physical and management plan which will provide a framework and structure for the responsible and sustainable stewardship of the MKSR.

4.1.17 Irreversible and Irretrievable Commitment of Resources

The proposed project would require a commitment of natural, physical, and human resources. In all of these categories, an irreversible and irretrievable commitment of resources would occur. A commitment of resources is irreversible when primary or secondary impacts limit the future options for a resource. An irretrievable commitment refers to the use or consumption of resources neither renewable nor recoverable for future use.

On-site construction of the Outrigger Telescopes would consume energy and building materials. In general, natural and propane gas and diesel fuel would be consumed directly by construction equipment and to generate electrical power and heat. The electrical power requirements of each Outrigger Telescope are estimated to be 30 kW (UH IfA 2001a). Four Outrigger Telescopes would require 120 kW and six would require approximately 180 kW. The additional electrical demand would be supplied largely thru fossil-fuel power generation by the electrical utility supplying the observatories. Petroleum products would continue to be consumed during operation; however, quantities would be significantly less than during construction. Construction materials such as steel, cement, and aggregate would also be expended. These physical resources are generally in sufficient supply, and their use by the project would not have an adverse effect on their availability. In some instances, at least some material resources such as structural steel and copper wiring could be reclaimed, recycled, and reused.

Although the proposal specifically addresses areas that are currently used and previously developed, a small portion of a previously disturbed area containing Wēkiu bug habitat would be displaced, and an additional small portion would be disturbed. This small impact to Wēkiu bug habitat would be mitigated by 3:1 habitat restoration.

With respect to human resources, trade and non-skilled laborers would be used during the on-site construction and installation of the Outrigger Telescopes. An estimated construction crew of 15 workers would be on the project site during the first 24 months, with an additional 15 workers overlapping the construction work by 5 months to assemble the domes and install the telescopes. Outrigger Telescopes operations would require four additional personnel for testing and four more when operations begin. Labor is generally not considered to be in short supply, and commitment to the project would not have an adverse effect on the continued availability of these resources.

4.2 CUMULATIVE IMPACT ASSESSMENT

The Council on Environmental Quality (CEQ) NEPA implementing regulations at 40 CFR 1508.7 define cumulative impacts as the incremental environmental impacts of the action when added to other "past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." Cumulative impacts can result from individually minor, but collectively significant, actions taking place over time.

As noted by CEQ in its handbook *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997), no universally accepted framework for cumulative effects analysis exists. NASA, however, has taken into account the principles and steps outlined in CEQ's handbook in developing the cumulative impact assessment of the Outrigger Telescopes Project contained in this section.

During the scoping process for this EIS, NASA consulted with interested agencies and the public who identified the following important cumulative impact areas associated with the Outrigger Telescopes Project: the Wēkiu bug and its habitat on Mauna Kea; the release of sewage system effluents into subsurface cinder at the summit; and, even more importantly, the central role of Mauna Kea in the cultural and spiritual life of Native Hawaiians.

NASA then determined that the general geographic scope of the cumulative impact analysis (i.e., the project ROI) would be the

Steps in the Cumulative Impact Assessment

- *Consult with interested organizations and the public through public scoping.*
- *Determine the geographical boundary or ROI.*
- *Determine the time frame to be evaluated.*
- *Determine the data sources available. Ask the community, local organizations, and in this case, the existing Mauna Kea observatories for information regarding reasonably foreseeable projects or activities. Review documentation on past and present projects within the geographical boundary.*
- *Assess the cumulative impacts based on individual or combined activity within the ROI.*

MKSR and a corridor surrounding the Mauna Kea Access Road and the Saddle Road. area where NASA recognized that this general project ROI would not be appropriate for all environmental resources considered, thus the ROI was adjusted where necessary to accommodate the analysis of cumulative impacts for a given resource. For example, the ROI used to assess cumulative impacts on air quality is larger than the ROI used to assess the incremental impact on air quality from the Outrigger Telescopes Project. NASA also determined that, in general, the time frame for the cumulative impact evaluation would extend from about 1964, before the first telescope was installed on Mauna Kea until the year 2033 when the lease agreement between the State of Hawaii and UH ends.

NASA consulted with the community, local organizations, government agencies, and the existing observatories on Mauna Kea to identify projects and activities on or near Mauna Kea that could occur within the ROI and within the reasonably foreseeable future, i.e., between the present and 2033. Section 4.2.2 identifies and describes these activities.

NASA then identified the potentially affected environmental resources, and evaluated both the project specific and cumulative impacts on these resources.

4.2.1 Past Activities

Table 4-7 identifies activities on or adjacent to Mauna Kea completed since astronomy facilities were established on Mauna Kea in May 1964. Figure 2-4 shows the locations of the observatories and Figure 2-8 shows the Mid-Elevation Support Facilities. The description of impacts of these past activities is based on State and Federal environmental evaluations prepared for those activities. These documents are referenced in Section 1.4 and in Chapter 10 of this EIS.

University of Arizona Site Test Telescope. Erected in May 1964 on Pu‘u Poliahu, the University of Arizona 0.3-m (12-in) Site Test Telescope was used intensively for a 6-month test program. The telescope and enclosure were subsequently removed from the mountain.

UH 0.6-m (24-in) Telescope. Built by The U.S. Air Force in 1968 at the base of the Mauna Kea summit ridgeline within a 0.0065-ha (0.016-ac) area (US IfA 2004f), this 0.6-m (24-in) telescope is the oldest operational telescope on Mauna Kea. The U.S. Air Force transferred the telescope to UH in 1970. Faculty and students in the UH Hilo astronomy program now use the telescope primarily for teaching and research. Although the telescope was constructed prior to NEPA requirements, operation of the UH telescope facilities was

TABLE 4-7. PAST ACTIVITIES

Project	Location	Sponsor	Description	Project Completion Date
University of Arizona 0.3-m (12-in) Site Test Telescope	Mauna Kea Astronomy Precinct	University of Arizona	0.3-m (12-in) Site Test Telescope. All equipment was removed upon completion of testing.	1964
UH 0.6-m (24-in) Telescope	Mauna Kea Astronomy Precinct	UH	0.6-m (24-in) optical telescope	1968
Planetary Patrol 0.6-m (24-in) Telescope	Mauna Kea Astronomy Precinct	Lowell Observatory	0.6-m (24-in) optical telescope. This facility was removed to make way for Gemini North.	1968
UH 2.2-m (88-in) Telescope	Mauna Kea Astronomy Precinct	UH	2.2-m (88-in) optical/infrared telescope	1970
United Kingdom Infrared Telescope (UKIRT)	Mauna Kea Astronomy Precinct	United Kingdom	3.8-m (12.5-ft) infrared telescope	1979
NASA Infrared Telescope Facility (IRTF)	Mauna Kea Astronomy Precinct	NASA	3.0-m (10-ft) infrared telescope	1979
Canada-France-Hawai‘i Telescope (CFHT)	Mauna Kea Astronomy Precinct	Canada/France/ University of Hawai‘i	3.6-m (12-ft) optical/infrared telescope	1979

TABLE 4-7. PAST ACTIVITIES (CONTINUED)

Project	Location	Sponsor	Description	Project Completion Date
Hale Pōhaku Mid-Elevation Support Facilities	Mauna Kea, along the Mauna Kea Access Road	UH	The original construction camp, including stone cabins and temporary buildings, has since been progressively upgraded and expanded to include dormitory and support facilities to accommodate astronomers and visitors to the summit of Mauna Kea.	1983
Mauna Kea Access Road	Mauna Kea	State of Hawai‘i and MKSS	A jeep trail constructed in 1964 was realigned in 1975 and improved in 1985, allowing safer access to the summit.	1985
James Clerk Maxwell Telescope (JCMT)	Mauna Kea Astronomy Precinct	United Kingdom/Canada/ Netherlands	15-m (49-ft) millimeter/submillimeter antenna	1986
Caltech Submillimeter Observatory	Mauna Kea Astronomy Precinct	Caltech/NSF	10.4-m (34-ft) millimeter/submillimeter antenna	1987
Installation of underground utilities	Saddle Road to summit of Mauna Kea	UH and individual observatories	UH funded the design and installation of the underground power lines connecting the HELCO system at Saddle Road to the summit distribution loop.	mid-1980s

TABLE 4-7. PAST ACTIVITIES (CONTINUED)

Project	Location	Sponsor	Description	Project Completion Date
Very Long Baseline Array (VLBA)	Mauna Kea Science Reserve (outside Astronomy Precinct)	NRAO/AUI/NSF	25-m (82-ft) centimeter-wavelength antenna	1992
W.M. Keck Observatory	Mauna Kea Astronomy Precinct	Caltech/ University of California/ CARA	Two 10-m (33-ft) optical/infrared telescopes (Keck I and Keck II)	1992/1996
Subaru Telescope	Mauna Kea Astronomy Precinct	Japan	8.2-m (27-ft) optical/infrared telescope	1999
Gemini North Telescope	Mauna Kea Astronomy Precinct	USA/UK/Canada/ Argentina/Australia/ Brazil/Chile	8.1-m (26.2-ft) optical/infrared telescope	1999
Jeep Trail Closure	Pu‘u Poli‘ahu	OMKM	A 274 to 366-m (300- to 400-yard) trail extending up to Pu‘u Poli‘ahu was closed to vehicles to minimize disturbance to cultural sites.	2001
Submillimeter Array (SMA)	Mauna Kea Astronomy Precinct	Smithsonian Astrophysical Observatory/ Taiwan	Eight 6-m (20-ft) submillimeter antennas	2002
Temporary Optical Test Sites at Keck	W.M. Keck Observatory	Caltech/ University of California	Two temporary optical test sites to assist in the development of the interferometry capability; were removed in 2003.	2003
GTE Fiber Optic Cable Installation	Saddle Road to Hale Pōhaku	UH IfA	A fiber optic telecommunications line was installed connecting the Mauna Kea observatories to the GTE Hawaiian Telephone Company fiber optic system.	1998

addressed in a State EIS completed in 1975 (UH IfA 1975).

Planetary Patrol 0.6-m (24-in) Telescope. The Lowell Observatory of Flagstaff, Arizona, installed and NASA funded a 0.6-m (24-in) telescope and dome enclosure on the Mauna Kea ridgeline in 1968 for long-term monitoring of the planets in our solar system. The telescope was decommissioned and the dome enclosure removed in 1994 when the Gemini North Telescope, which now occupies the site, was constructed.

UH 2.2-m (88-in) Telescope. When this NASA-funded 2.2-m (88-in) telescope was constructed on 0.06 ha (0.14 ac) of the Mauna Kea summit ridgeline in 1970, it was the seventh largest optical/infrared telescope in the world and the first major construction on the mountain. This telescope is now operated by UH from the IfA facility in Hilo, Hawai‘i (UH IfA 2004f). Funded jointly by UH and NASA until 1997, UH now funds it entirely. Operation of the UH telescope facilities was addressed in a State EIS completed in 1975 (UH IFA 1975).

United Kingdom Infrared Telescope (UKIRT). Constructed in 1979 on a 0.49-ha (1.20-ac) parcel at the base of the ridgeline on the summit of Mauna Kea, the UKIRT is a 3.8-m (12.5-ft) diameter telescope optimized for observations in the infrared portion of the spectrum (JACH 2003). The Joint Astronomy Center operates the telescope from the UKIRT headquarters office in Hilo. A State Environmental Impact Statement was completed for the UKIRT facility in 1975 (UH IFA 1975).

NASA Infrared Telescope Facility (IRTF). Like the UKIRT, this 3-m (10-ft) telescope located at the summit of Mauna Kea is optimized for infrared observations. The telescope is operated and managed for NASA by UH from the IfA Facility in Hilo (IRTF 2001). In 1975, UH completed a State Environmental Impact Statement to evaluate the construction of the IRTF facility (UH IFA 1975). NASA also completed a separate Federal Environmental Impact Analysis for the IRTF facility in 1975 (NASA 1975). Today, IRTF serves as a national infrared observing facility for U.S. astronomers, and is used by UH faculty and students approximately 15 percent of the time.

Canada-France-Hawai‘i Telescope (CFHT). Funded jointly by Canada, France and State of Hawai‘i through UH, this optical telescope has a 3.6-m (12-ft) aperture and was completed in 1979 on a 0.74-ha (1.84-ac) parcel. The CFHT headquarters office is located in Waimea. A State EIS was completed in 1974 for the CFHT facility (CFHT 1974).

Hale Pōhaku Mid-Elevation Support Facilities. It is hazardous for persons to go directly from sea level to high altitudes without acclimatizing at an intermediate altitude. For this reason, a construction camp was built in 1968 when work began on the UH 2.2-m (88-in) Telescope. The camp was two-thirds of the way up the mountain at 2,804 m (9,200 ft) along the Mauna Kea Access Road. Three preexisting stone cabins were in this area. Subsequently, four additional temporary buildings were added for visitors and workers on the mountain.

In 1983, permanent mid-level facilities were opened at Hale Pōhaku. The original four observatory operators on the mountain, UH, NASA, United Kingdom, and Canada-France-Hawai‘i, contributed a total of $5.7 million for construction. A 20-person dormitory was added in 1990.

The current complex includes dormitories, separate employee housing, offices, and a large common area equipped with a kitchen, dining hall, and recreational areas. In addition to the 72 rooms now available for astronomy support personnel and astronomers at Hale Pōhaku, five rooms are available for use exclusively by the Mauna Kea Support Services (MKSS) food and lodging staff (MKSS 2004c). A revised State EIS for the Hale Pōhaku Master Plan was completed in 1980 (State of Hawai‘i 1980).

Also in 1983, a Visitor Information Station (VIS) named for Ellison Onizuka, an astronaut and Hawaii native who perished in the *Challenger* explosion, was added to the Hale Pōhaku complex. Located approximately 198 m (650 ft) south of the main buildings at Hale Pōhaku (UH 2000b), the VIS includes an 88-square meter (m^2) (950-square foot (ft^2)) interpretive center for visitors to the mountain.

Of the four temporary buildings, two were removed and two relocated after the mid-level facilities were completed in 1983. Two were completely refurbished and relocated off the mountain to the Mauna Kea State Park. Two were moved south to create the first phase of the current construction camp, used initially by the Keck I Telescope workers. The need for this camp was realized in the mid-1980s when the scope and pace of observatory development increased. A Supplemental State EIS amending the 1983 MKSR Complex Development Plan was completed in 1985 for this construction camp housing.

The second phase of the camp included the addition of four cabin-like structures, raised off the ground on wood posts and nestled amid the *māmane* trees, with exteriors designed to blend into the surroundings. Each cabin has four bedrooms, with two beds each, for a total of 32 beds. Completed in 1994 for the Subaru project, the cabins housed the construction workers and some workers for the Keck II Telescope and the Submillimeter Array (SMA). The original relocated buildings currently provide office space, storage areas, and a multipurpose classroom. The cabins provide accommodations for VIS and Ranger staff and occasionally for UH Hilo astronomy program participants and special groups (MKSS 2004c). A portion of the camp could be used if future development requires living space for construction workers.

Today the Hale Pōhaku Mid-Elevation Support Facilities, including parking areas, are contained within a 7.8-ha (19.2-ac) footprint (MKSS 2004d).

Mauna Kea Access Road. A gravel road connecting the Saddle Road to Hale Pōhaku was constructed in the 1930s. A jeep trail from Hale Pōhaku to the summit was added in 1964 when the first telescope was installed. In 1975, the jeep trail was realigned to eliminate some of the steep grades and sharp turns, lengthening the original 10.5-km (6.5-mi) road to approximately 13.7 km (8.5 mi) (UH 1987).

The improved roadway was safer, but still dusty. In 1985, with funding from the State of Hawai‘i and W.M. Keck Observatory infrastructure contribution, the State of Hawai‘i Department of Transportation (DOT) designed a 6.1-m (20-ft) wide roadway beginning at Hale Pōhaku and looping around the summit. A portion of the roadway between the 3,597 m (11,800 ft) elevation level and the summit was paved to reduce dust and improve safety. Future plans include paving the roadway between Hale Pōhaku and the 3,597 m (11,800 ft) elevation level and developing additional parking areas and two runaway truck ramps, although this project is not currently funded (UH 1999). When the upper portion was paved in the early 1990s, the road from Hale Pōhaku to the summit was named after John A. Burns, the governor of Hawai‘i during the earliest years of astronomy development.

James Clerk Maxwell Telescope (JCMT). The 15-m (49-ft) JCMT is the world's largest radio telescope designed specifically to operate in the submillimeter wavelength region of the spectrum (JACH 2003). The telescope was completed in 1986 on a 0.61-ha (1.5-ac) parcel on the Mauna Kea summit plateau, west of the Caltech Submillimeter Observatory and south of the SMA. A joint venture between the United Kingdom, Canada, and the Netherlands, JCMT is operated by the Joint Astronomy Center from its headquarters office in Hilo (JACH 2003). The environmental impacts of the JCMT were addressed in the 1983 Mauna Kea Science Reserve: Complex Development Plan Final EIS (UH 1983a).

Caltech Submillimeter Observatory. The Caltech Submillimeter Observatory, completed in 1987, houses a 10.4-m (34-ft) radio telescope designed to work in the submillimeter portion of the spectrum within a compact 18-m (60-ft) dome. Caltech constructed this telescope on a 0.30-ha (0.75-ac) parcel between the three summit cinder cones —Pu'u Poli'ahu to the west, Pu'u Hau'oki to the north, and Pu'u Wēkiu to the east (Caltech 1982). Caltech operates the telescope under a National Science Foundation (NSF) contract and manages it from the Caltech Submillimeter Observatory headquarters office in Hilo. A combined State and Federal EIS was completed in 1982 (Caltech 1982).

Installation of Underground Utilities. In 1982, following a 16-year attempt to provide off-site electrical power to the summit the State legislature appropriated funds for the Department of Accounting and General Services to conduct a second preliminary design and planning study for a permanent connection to the HELCO system. Based on the results of the study, during the mid-1980s, UH funded the design, construction, and installation of underground power lines connecting the HELCO system at Saddle Road to a summit distribution loop. Individual observatories funded the underground connection from their respective facilities to the summit loop. HELCO conducted the conduit installation and continues to be responsible for maintenance of the electrical system. These permanent power lines replaced a suite of generators that had been upgraded and augmented during the history of the astronomy complex (UH 1987).

Very Long Baseline Array (VLBA). The VLBA is an aperture-synthesis radio telescope consisting of 10 25-m (82-ft) remotely operated antennas, located across the country, from the U.S. Virgin Islands in the east to Hawai'i in the west. All 10 antennas are located in United States territories, and the entire project is Federally funded by NSF and managed from a central headquarters office in Socorro, New Mexico. The Hawai'i antenna was erected in 1992 at 3,719 m (12,200 ft), a lower elevation than the other observatories, on a 0.81-ha (2.01-ac) subleased parcel. A combined State and Federal Supplemental EIS was completed in 1988 for the VLBA Antenna Facility (UH IfA 1988) as a project-specific amendment to the 1983 *Mauna Kea Science Reserve: Complex Development Plan Final Environmental Impact Statement* (UH 1983a).

W.M. Keck Observatory. The W.M. Keck Observatory houses the world's two largest optical/infrared telescopes. These twin 10-m (33-ft) telescopes are located on the north side of the Mauna Kea summit on a 2-ha (5-ac) subleased parcel. The Keck I Telescope was completed in 1992 and the Keck II Telescope in 1996. Although the telescopes are usually used individually for astronomical research, about 10 percent of the time, the two telescopes are used together as an interferometer (UH IfA

1998b). The W.M. Keck Observatory is managed by CARA, a non-profit organization wholly owned by Caltech and the University of California. The Observatory headquarters office is located in Waimea. The 1983 *Mauna Kea Science Reserve: Complex Development Plan Final Environmental Impact Statement* (UH 1983a) included an environmental evaluation of the W.M. Keck Observatory site and the potential impacts of constructing both Keck Telescopes.

Subaru. Formerly known as the Japan National Large Telescope (JNLT), the Subaru Telescope is an 8.2-m (27-ft) optical infrared telescope located on Pu‘u Hau‘oki, just west of the W.M. Keck Observatory. Construction began in 1991 and first light was achieved in 1999 (Subaru 2003).

The footprint of Subaru totals 2.168 ha (5.356 ac). Operated by the National Astronomical Observatory of Japan, the Subaru Telescope Headquarters office is located in Hilo. The power and communication systems at the summit were extended, and the dirt road accessing the Subaru site was paved in conjunction with observatory construction. Based on the project description completed in 1991 for the JNLT (UH IfA 1991), the State Office of Environmental Quality Control determined that all environmental impacts had been addressed in the 1983 *Mauna Kea Science Reserve: Complex Development Plan Final Environmental Impact Statement* (UH 1983a).

Gemini North Telescope. Gemini North is a twin to the Gemini South telescope located on Cerro Pachón in Chile. Each telescope has an 8.1-m (26.2-ft) diameter mirror. Gemini North was completed in 1999 on 0.78 ha (1.93 ac) of the Mauna Kea summit ridge between the 2.2-m (88-in) UH Telescope and the CFHT on the site of the former UH 0.6-m (24-in) Planetary Patrol Telescope (UH IfA 1994). Originally, the United States provided 50 percent of the observatory funding in partnership with the United Kingdom (25 percent), Canada (15 percent), Chile (5 percent), Argentina (2.5 percent), and Brazil (2.5 percent). The NSF was designated as the Federal agency for the project (NSF 1993). The Gemini Headquarters office is located in Hilo. A Federal EA was completed for the Gemini Telescope in 1993 (NSF 1993). The environmental impacts of Gemini North were addressed in the 1983 *Mauna Kea Science Reserve: Complex Development Plan Final Environmental Impact Statement* (UH 1983a).

Jeep Trail Closure. In 2001, the Office of Mauna Kea Management (OMKM) officially closed the unpaved jeep trail extending up the side of Pu‘u Poli‘ahu (originally cut for the installation of the University of Arizona Site Test Telescope) by erecting barricades and posting signs prohibiting vehicular access, after Kahu Kū Mauna, the cultural advisors to the Mauna Kea Management Board, requested the closure to prevent vehicular disturbance to cultural sites. The 274 to 366-m (300 to 400-yard) trail is still accessible to hikers visiting the peak of Pu‘u Poli‘ahu and spiritual and cultural sites located on Mauna Kea (OMKM 2001).

Submillimeter Array (SMA). The SMA, a collaborative project of the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy & Astrophysics of Taiwan, was the world’s first interferometer dedicated to submillimeter astronomy. The array comprises eight 6-m (20-ft) antennas that can be moved among 24 pad locations. Astronomical signals from each antenna are transmitted through fiber optic cables to a supercomputer within the observatory called a Correlator (SMA 2004a). The SMA was completed in 2003 on a 1.2-ha (3-ac) subleased parcel with additional easements for outlying antennas. The Smithsonian Astrophysical Observatory headquarters office is located in Cambridge, Massachusetts. The SMA is operated from a base facility in Hilo.

The SMA site can be accessed from a road that branches off the Mauna Kea Access Road and proceeds north through "Submillimeter Valley," past the Caltech Submillimeter Observatory and the JCMT. In connection with the SMA construction, the road extending from JCMT to the Pu'u Poli'ahu road was paved and a drainage channel added to the east side of the roadway (UH IfA 1994). A project description and State Environmental Review were completed in 1994 for the SMA (UH IfA 1994). Based on this project description and review, the State Office of Environmental Quality Control determined that all environmental impacts had been addressed in the 1983 *Mauna Kea Science Reserve: Complex Development Plan Final Environmental Impact Statement* (UH 1983a).

Temporary Optical Test Sites. Two temporary optical test sites were constructed on the W.M. Keck Observatory sublease, adjacent to the Keck II Telescope, to assist in developing the interferometry capability of the two telescopes. The test sites were connected to the basement of the Keck II Telescope by underground optical paths. The equipment was dismantled and removed in 2003. A Federal EA for the Temporary Optical Test Sites was completed in September 1998 (NASA 1998).

GTE Fiber Optic Cable Installation. A fiber optic telecommunications line was installed connecting the Mauna Kea Observatories to the GTE Hawaiian Telephone Company (GTE HTCo) fiber optic system. An overhead fiber optic line was installed between Pōhakuloa and the HELCO electrical substation at Pu'u Kalepeamoa, then through an underground conduit to Hale Pōhaku, parallel to existing underground electrical lines. The new fiber optic cables were then connected to an existing fiber optic link to the summit from Hale Pōhaku. All construction and installation complied with GTE HTCo standards and applicable State and County requirements (GTE HTCo and UH IfA 1995). A project description and environmental review were completed in 1995 for the GTE fiber optic cable installation (GTE HTCo and UH IfA 1995). Based on the project description and review, the State Office of Environmental Quality Control determined that the environmental impacts for this project had been addressed in the 1983 *Mauna Kea Science Reserve: Complex Development Plan Final Environmental Impact Statement* (UH 1983a).

4.2.2 Reasonably Foreseeable Future Activities

Table 4-8 identifies proposed projects on or adjacent to Mauna Kea that could reasonably contribute to cumulative impacts. For the purposes of this evaluation, reasonably foreseeable refers to initiation of on-site construction or implementation of a planned project on or near Mauna Kea through December 31, 2033, the end of the MKSR lease agreement between UH and the State of Hawaii (State of Hawai'i 1968). If a project is not currently being pursued, but was included in the 2000 MKSR Master Plan, it was presumed to be reasonably foreseeable unless current information indicates otherwise.

This section identifies reasonably foreseeable future astronomy and non-astronomy-related projects within the ROI.

TABLE 4-8. REASONABLY FORESEEABLE FUTURE ACTIVITIES

Project	Location	Sponsor	Description	Projected Completion Date
1-m Class Instructional Telescope	UH 0.6-m (24-in) Telescope	UH, Hilo	UH-Hilo will assume responsibility for the existing 0.6-m (24-in) observatory site, and the new telescope it will place there, upon initiation of building renovation work (projected for third quarter of 2005).	2006
PanSTARRS	2.2-m (88-in) Telescope on Mauna Kea or Haleakala, Maui	U.S. Air Force	PanSTARRS would consist of four 1.8-m (6-ft) telescopes, each with a 3-degree field of view and a 1-billion-pixel digital camera, making it possible to observe the entire available sky several times during the dark portion of each lunar cycle.	2008
Site Testing and Monitoring	Mauna Kea Astronomy Precinct	UH IfA	UH IfA is proposing to install site-testing equipment in the northwest quadrant of the Astronomy Precinct and on the summit ridge, to assess the quality of those locations for astronomical observations. The northwest plateau installation would be temporary. The seeing monitor component of the summit ridge installation may be proposed as a permanent addition to the infrastructure.	2007
TMT	Astronomy Precinct Mauna Kea Science Reserve	UC/Caltech/ AURA/Canada	A Next Generation Large Telescope, with the ability to provide optical/infrared capabilities 10 times that of the largest exiting telescopes, is proposed to be located within the northwest plateau of MKSR.	2014

TABLE 4-8. REASONABLY FORESEEABLE FUTURE ACTIVITIES (CONTINUED)

Project	Location	Sponsor	Description	Projected Completion Date
OHANA	Six observatories on Summit of Mauna Kea	Paris Observatory, NASA, CFHT, UH, Gemini, and Keck	The Paris Observatory, in collaboration with several other Mauna Kea Astronomy Precinct observatories, proposes to develop an optical/infrared interferometer using an array of exiting telescopes on the summit of Mauna Kea, including UKIRT, CFHT, and IRTF.	Unknown
Redevelopment of CFHT, IRTF, and UKIRT	Summit of Mauna Kea	CFHT, NASA, UK	Redevelopment of 3 to 4-m (10 to 13-ft) telescope facilities.	Unknown
SMA Expansion	Summit of Mauna Kea	Smithsonian Astrophysical Observatory/ Taiwan	A conceptual plan considering adding 12 new antennas and 24 additional concrete pads.	Unknown
Visitor Information Station Expansion	Hale Pōhaku		A proposal to expand the Visitor Information Station at Hale Pōhaku.	Unknown
Completion of Mauna Kea Access Road	Mauna Kea Access Road		The Mauna Kea Access Road would be paved from Hale Pōhaku to 3,597-m (11,800-ft) elevation.	Unknown
End of Lease	MKSR	UH	All structures will be removed from Mauna Kea at the end of the lease (2033) unless otherwise negotiated.	2033
Training at PTA for Stryker Brigade Combat Team Army Transformation Project	Pōhakuloa Training Area	U.S. Army	The Stryker Brigade Combat Team Army Transformation Project would include constructing training and support facilities, acquiring additional lands, and changing training activities and locations.	2007

TABLE 4-8. REASONABLY FORESEEABLE FUTURE ACTIVITIES (CONTINUED)

Project	Location	Sponsor	Description	Projected Completion Date
Remotely Operated Microwave Facility	Eastern slope of Mauna Kea	County of Hawaiʻi Police Department	The County of Hawaiʻi Police Department proposes to construct a remotely-operated microwave facility on a 389-m^2 (4,192-ft^2) portion of the eastern slope of Mauna Kea at 2,475 m (8,121 ft), south of the MKSR.	December 2008
Keanakolu Road Improvements	Mauna Kea	Federal Highway Administration (FHWA)	FHWA plans to rehabilitate deteriorated road conditions along 19.9 km (12.4 mi) of Keanakolu Road, from its junction with the Mauna Kea Access Road to the entrance to Hakalau Forest National Wildlife Refuge.	Unknown
Development of DHHL Land Acquisition	Base of Mauna Kea Access Road	DHHL	DHHL began planning the long-term land use and management of 22,734 ha (56,178 ac) of public land in Humuʻula and Piʻihonua. Land uses considered include homesteading, commercial/service businesses, ecotourism, forestry, ranching, farming, cinder quarrying, gorse control, and resource areas.	Unknown
Saddle Road Improvements	State of Hawaiʻi DOT	State of Hawaiʻi	A long-term DOT highway construction project that includes improvements and modifications to the Saddle Road between the Hilo side and Kona side of the island of Hawaiʻi, including approximately 402 km (250 mi) of road to be modernized to meet American Association of State Highway and Transportation Officials standards.	Unknown

NASA has determined that a number of projects on Mauna Kea mentioned in other environmental documents (e.g., the 2000 MKSR Master Plan and the 2000 MKSR Master Plan EIS) are not reasonably foreseeable and are addressed at the end of this section.

The reasonably foreseeable future projects are still conceptual in nature. Currently no construction design or operation management plans with quantitative information to use in assessing impacts to environmental resource areas exist.

NASA applied general assumptions as appropriate to reasonably foreseeable future astronomy projects on Mauna Kea to evaluate their cumulative impacts. Additional resource-specific assumptions are provided in the individual environmental resource sections. Table 4-9 summarizes the characteristics of the reasonably foreseeable projects.

Generally Applicable Assumptions for Reasonably Foreseeable Future Activities

- With the exception of buildings to be modified, existing facilities will continue to employ the same number of staff, generate the same amount of waste (solid, hazardous, wastewater), and use the same amount of domestic water and electricity.
- During construction activities, the contractor would be responsible for dust and noise control, and air monitoring as required by applicable environmental regulations, permits, and other agreements.
- On-site electrical generators will provide additional power for equipment during construction and installation of future projects at sites where electrical power is not currently available.
- Equipment needed for on-site construction will be staged at either the summit staging area or the construction staging area at Hale Pōhaku.
- Workers will travel, sometimes in carpools, from Hale Pōhaku to the summit as needed.
- Construction and installation workers, sometimes in carpools, will use light-duty, gasoline-fueled vehicles to travel to the site from off-mountain locations 5 days per week (approximately 120 km (75 mi) per day).
- Water would continue to be trucked to the summit and to Hale Pōhaku, becoming domestic wastewater with subsurface disposal.
- It is assumed that on-site construction, installation, and operation of the future projects will adhere to stipulations in the MKSR Master Plan.
- Construction contractors and their personnel and telescope operators will comply with CDUP requirements, mitigation plans, and best management practices, as stipulated for each project.
- All future facility designs will incorporate new design guidelines — surface treatments (e.g., reflective versus non-reflective), geometrical designs, textures, and materials — to blend facilities into the surrounding environment and minimize visual impacts. All proposed development plans for future projects will be reviewed by the OMKM.

TABLE 4-9. KEY CHARACTERISTICS OF REASONABLY FORESEEABLE FUTURE ASTRONOMY ACTIVITIES

Project	Potential Timing			Type of Project			Construction Effort				Operation Workforce			
	2004-2007	2007-2032	2033	Recycle/Minor Addition	Facility Addition	New Facility	Smaller than OTP	Similar to OTP	Larger than OTP	Much Larger than OTP	Smaller than OTP	Similar to OTP	Larger than OTP	Much Larger than OTP
1-m UH	●			●			●				●			
PanSTARRS	●			●	●		●	●			●			
Site Testing and Monitoring	●			●			●				●			
TMT		●				●				●				●
OHANA	●			●			●				●			
Redevelopment of CFHT, IRTF, and UKIRT		●		●	●				●			●		
SMA Expansion		●			●		●				●			
Visitor Information Station Expansion		●			●			●	●			●	●	
Completion of Mauna Kea Access Road		●			●			●			●			
End of Lease			●			●				●				

Acronyms:

OTP = Outrigger Telescopes Project

POTENTIAL TIMING

1. 2004-2007: Project plans have advanced beyond the concept phase; project potentially initiated within the same timeframe as OTP.

2. 2007-2032: Project currently at conceptual stage only; project is unlikely to be initiated within the same timeframe as OTP.

3. 2033: End of current lease; consider bounding scenarios: all observatories will either continue to operate or be demolished.

TYPE OF PROJECT

1. Recycle/Minor Addition(s): Recycle projects assumed to be primarily internal to existing observatory facility with only minor addition(s) to current facility buildings resulting in little change in the facility footprint on the site. Minor addition(s) would occur within the currently disturbed area of the lease but less than OTP.

2. Facility Addition: Approximately same scale of additional observatory development as OTP. Additional development would occur within the confines of the already disturbed area(s) of the observatory site.

3. New Facility: Project would require either a new observatory site or extensive new facility work on an existing observatory site resulting in a substantially larger facility footprint on the site.

CONSTRUCTION EFFORT (i.e., Onsite Construction and Installation)

1. Smaller than OTP: Workforce about ½ that of OTP; magnitude and duration less than OTP.

2. Similar to OTP: Workforce about same size as OTP; magnitude and duration about same as OTP

3. Larger than OTP: Workforce larger than that required by OTP; Magnitude and duration greater than OTP.

4. Much larger than OTP. Magnitude, duration, and workforce much larger than that required by OTP.

OPERATION WORKFORCE

1. Smaller than OTP: Operation workforce about same as current facility.

2. Similar to OTP: Additional operation workers added; workforce about same size as OTP.

3. Larger than OTP: Operational Workforce larger than that required by OTP.

4. Much larger than OTP. Operational workforce much larger than that required by OTP.

REASONABLY FORESEEABLE FUTURE ASTRONOMY PROJECTS

- *1-m Class Instructional Telescope*
- *PanSTARRS*
- *Site Testing and Monitoring*
- *TMT*
- *OHANA*
- *Redevelopment of CFHT, IRTF, and UKIRT*
- *SMA Expansion*
- *Visitor Information Station Expansion*
- *Completion of the Mauna Kea Access Road*
- *End of Lease*

REASONABLY FORESEEABLE NON-ASTRONOMY RELATED PROJECTS

- *Army Transformation*
- *Remotely Operated Microwave Facility*
- *Keanakolu Road Improvements*
- *Development of DHHL Land Acquisition*
- *Saddle Road Improvements*

REASONABLY FORESEEABLE FUTURE PROJECTS

Replacement of the UH 0.6-m (24-in) with a 1-m (3.3-ft) Class Instructional Telescope. UH Hilo will acquire the UH 0.6-m (24-in) Telescope and proposes to replace it with a 1-m (3.3-ft) class instructional telescope. The existing dome enclosure would be renovated. The telescope would primarily be operated remotely from the UH Hilo campus with infrequent (3 to 4 nights per month) visits to the site, reducing the number of personnel visiting the site and the amount of traffic on the mountain. The facility would use equal or less electricity. UH Hilo has notified OMK M of their intent and will be submitting a formal application later this year. NSF has committed to funding the new telescope through a major research instrument grant, and UH will fund the building renovations. If approved, construction would begin in September 2005 and be completed by September 2006 (UH 2004).

Panoramic Survey Telescope and Rapid Response System (PanSTARRS). PanSTARRS is an innovative design for a wide-field imaging system being developed at UH IfA. The primary objective of PanSTARRS is to detect and characterize Earth-approaching objects, both asteroids and comets, that might pose a danger to our planet. This project would use four 1.8-m (6-ft) telescopes, each with a 3-degree field of view, to observe the available sky several times during the dark portion of each lunar cycle. Each telescope would be equipped with a one-billion-pixel digital camera.

This telescope grouping could obtain a huge amount of valuable information applicable to many other kinds of scientific programs, including mapping the amount of dark matter in the universe and looking for changes in variable stars to help understand the birth and death of stars and planets (UH IfA 2004a).

Sites in the Mauna Kea Science Reserve and Haleakala High Altitude Observatory, located on the islands of Hawaiʻi and Maui, respectively, are being considered. Site selection for PanSTARRS would be based on technical, environmental, and cultural resource factors and is expected within the next year. It is currently estimated that, if a site is selected within the next year, the project would be completed by 2008 (UH IfA 2004a). If Mauna Kea is chosen, the UH 2.2-m (88-in) Telescope would be decommissioned so its site could accommodate PanSTARRS. Traffic to the PanSTARRS observatory would be approximately the same as today. Although energy use has not yet been estimated, the increase in power needs for PanSTARRS is not expected to be substantial because of the comparative energy efficiency of modern equipment.

Site Testing and Monitoring. UH IfA is proposing to install temporary site testing equipment in the northwest quadrant of the Astronomy Precinct at a location along the existing jeep trail. This general area has been designated in the 2000 MKSR Master Plan as the proposed site for the Next Generation Large Telescope (NGLT). The current concept for the NGLT is the Thirty-Meter Telescope (TMT), as described below. The purpose of this site testing would be to assess the quality of the northwest plateau for astronomical observations and to determine its suitability for an NGLT project such as the TMT. The principal component of the site testing equipment would be a 6-m (20-ft) tower on top of which is mounted a seeing monitor instrument and its enclosure, together with a weather station module. Additional equipment would include a 30-m (98-ft) mast supporting microthermal probes and wind sensors, a pair of acoustic sounding instruments at ground level and a solar power unit to provide electricity for the instruments. For the mast, the possibility of using a deployable trailer-mounted unit is being explored. Testing is expected to begin in late 2004 or early 2005 and continue for approximately three years, after which all equipment would be dismantled and removed.

UH is also developing plans to install site testing equipment on the summit ridge at a location between CFHT and Gemini. The purpose of this installation is to assess the astronomical quality of the summit ridge using the same type of instruments that would be used on the northwest plateau. This would provide a reliable comparison between the two siting areas, as well as valuable information for the planning of possible future upgrades and replacements of the existing summit ridge observatories. It is also likely that the seeing monitor component would be useful for the ongoing operations of the existing observatories. The solar power unit would not be needed, as electricity is available nearby. Any use of the acoustic sounding instrument or the mast would be temporary, and in the case of the mast, it is expected that a deployable trailer-mounted unit would be used. Depending on how useful it turns out to be, UH IfA may propose to retain the 6-m (20-ft) tower and seeing monitor as a permanent addition to the observatory infrastructure.

Thirty Meter Telescope (TMT). Advances in telescope technology have made it conceivable to build an optical/infrared telescope roughly 10 times as powerful as the largest current telescopes (the twin Keck Telescopes). Such a development was envisaged in the 2000 MKSR Master Plan as the Next Generation Large Telescope (NGLT). A number of conceptual designs have been considered for an NGLT (UH IfA 2003). At the present time the leading candidate is the TMT, a concept being pursued through a collaboration between the University of California, Caltech, the Association of Universities for Research in Astronomy (AURA), and the Association of Canadian Universities for Research in Astronomy (ACURA). In addition to Mauna Kea, the TMT collaboration is also considering sites in Chile and Mexico. Features from the conceptual designs of the Giant Segmented Mirror Telescope, the California Extremely Large Telescope (CELT) and the Very Large Optical Telescope are being incorporated into the TMT design.

The site within the Astronomy Precinct being considered for the NGLT is located on the northern plateau. This site was chosen for a number of reasons, including lower potential for wind damage to the facility and lower visibility from off-mountain locations (UH IfA 2000b). Site testing is proposed for the northwest plateau, as described above for site testing and monitoring. Similar tests are also being conducted at the Chile and Mexico sites. The TMT project is currently in the preliminary design phase; funding for construction has not yet been acquired. Should funding for construction be obtained in the future, offsite construction is expected to begin about four years later, with first light anticipated no earlier than 2014.

Optical Hawaiian Array for Nano-Radian Astronomy (OHANA). The Paris Observatory, in collaboration with several Mauna Kea observatories, proposes to develop a fiber optic interferometer using an array of existing telescopes on the summit of Mauna Kea, including two 10-m (33-ft) telescopes (Keck I and Keck II), two 8-m (26-ft) telescopes (Subaru and Gemini), and several 3 and 4-m (10 and 13-ft) telescopes (IRTF, CFHT, and UKIRT) (CFHT 2000c). These telescopes provide diverse capabilities for future interferometric observation, including baselines ranging from 50 to 1,000 m (164 to 3,281 ft), for more sophisticated and complex studies of stars, circumstellar phenomena, and extragalactic targets than have previously been possible (CFHT 2000b).

An initial collaboration of the interested parties, including CFHT, Keck, Gemini, UH, NASA (through IRTF), and Paris Observatory, identified three phases of the OHANA project. Phase I included three parts: (1) investigate the interface between adaptive optics and optical fibers by designing an injection module to test on some of the existing telescopes, (2) identify funding for the second phase by recruiting interested parties, and (3) determine the scientific advances possible with the proposed fiber optic interferometer. This phase has largely been completed except for testing the injection module on three of the seven telescopes used in the study (Subaru, IRTF, and UKIRT). Phase II, currently under way, involves connecting short-range telescope pairs to evaluate the project's feasibility. This is being tested at two sites: (1) between the two Keck Telescopes at a technically low-risk test site (because the operational characteristics of the existing interferometer are known) and (2) between Gemini and CFHT. Because these last two facilities are not currently connected, additional equipment is being installed to synchronize the telescopes. Phase III involves the operation of the future fiber optic interferometer and is, therefore, contingent on the success and completion of the first two phases. Based on the success of Phase II, funding would be provided proportionately by observatories involved in the strategic, logistic, and operational plans for the interferometer (CFHT 2004).

The OHANA Project currently plans to use existing infrastructure. Due to the cost of the special type of fibers required, during the experimental phases of the project, the same set of fibers will be used in existing conduits for testing between facilities. However, depending on which telescopes are being connected, there may be a possibility that fibers would be run over the ground.

If the project moves into Phase III, the administrators intend to use existing utility ducts to lay fiber cables. The location of the control center(s) is speculative; however, a space in one or more of the existing facilities is expected to be available. No external construction is expected to be necessary (CFHT 2004).

OHANA would operate only 1 to 3 nights per semester and only on very specific targets (CFHT 2004).

Redevelopment of CFHT, IRTF, and UKIRT. Redevelopment of the 3 to 4-m (10 to 13-ft) telescope facilities on Mauna Kea (CFHT, IRTF, UKIRT) was discussed in the MKSR Master Plan (UH 2000b). However, there are no proposals under consideration to pursue these projects.

SMA Expansion. A conceptual plan for SMA, discussed in the 2000 MKSR Master Plan, considers adding up to twelve new transportable antennas and 24 additional concrete pads to the original array (UH 1999). It now appears that any expansion of SMA may be substantially less than this, including only a few additional antennas and pads and the possible relocation of three existing pads located at the base of Pu‘u Poli’ahu to avoid interference with cultural sites. The existing array, however, has only been operational since November 2003. Any plans to expand are only conceptual at this time, and no funding is in place. Expansion would not be included in the near-term plans for the facility.

VIS Expansion. A proposed VIS expansion at Hale Pōhaku in conjunction with the proposed Mauna Kea Astronomy Education Center and a separate OMKM-proposed expansion are not currently funded.

Completion of the Mauna Kea Access Road. If the TMT Project is located on Mauna Kea, paving of the Mauna Kea Access Road likely would be completed. This would include paving the road from Hale Pōhaku to the 3,597-m (11,800-ft) elevation, and construction of additional parking areas and two runaway truck ramps. This project is not currently funded.

End of Lease. As a reasonably foreseeable future astronomy project, End of Lease in 2033 could result in a variety of outcomes ranging from continuation of observatory activities to complete removal of all observatories from the mountain. Because of this range of possibilities, the End-of-Lease is addressed separately in Section 4.2.15.

REASONABLY FORESEEABLE NON-ASTRONOMY-RELATED PROJECTS

Training at Pōhakuloa Training Area (PTA) for Stryker Brigade Combat Team Army Transformation Project. The use of PTA would increase in connection with the Stryker Brigade Combat Team Army Transformation Project. PTA is located in the saddle between Mauna Kea and Mauna Loa. This project would include constructing training and support facilities, acquiring additional land, and modifying training activities and locations. Although these proposed actions would take place at various locations at PTA, the primary project actions in the vicinity or north of Saddle Road would contribute to the cumulative impacts of the Proposed Action. This EIS considered the following in connection with the Army Transformation Project: construction of a tactical vehicle wash facility; construction of a range maintenance facility, a runway upgrade, and extension at Bradshaw Army Airfield; construction of a military vehicle trail; installation of an information infrastructure architecture fiber optic cable throughout the cantonment area; and construction of fixed tactical Internet antennas at various points along the Saddle Road. An EIS has been completed to evaluate the environmental impacts of these and other associated Army Transformation projects (USACE 2004).

Remotely Operated Microwave Facility. Under Special Permit No. 1220 (SPP1220), the County of Hawai‘i Police Department proposed to construct a remotely operated microwave facility on a 389-m^2 (4,192-ft^2) portion of Tax Map Key (TMK) 4-1-006:007 in the State Land Use agricultural district. This district, referred to as Iolehaelea, is located on the eastern slope of Mauna Kea 2,475 m (8,121 ft) south of the MKSR. This proposed project would include construction of a 15-m (50-ft) tower and antenna, equipment shelter, and related improvements to be completed within 5 years of the effective date of the permit, issued by the County of Hawaiʻi Department of Public Works-Building Division on December 17, 2003. Vehicles and equipment accessing the proposed project site would not be expected to use the Mauna Kea Access Road because other trails likely would provide a more direct route to the site.

Keanakolu Road Improvements. The Federal Highway Administration (FHWA) plans to rehabilitate a 19.9 km (12.4 mi) deteriorated portion of Keanakolu Road (also known as Mana Road) from its junction with the Mauna Kea Access Road to the entrance to Hakalau Forest National Wildlife Refuge to improve the road's unusually rough and hazardous driving conditions and improve USFWS administrative access to Hakalau. The FHWA plans to improve only areas with the most severe problems. Construction would occur only within the disturbed areas of the existing road and could consist of spot improvements such as adding coarse aggregate (gravel) to severely deteriorated surface areas to improve drivability; paving or reducing the vertical alignment of short portions of steeper grades to improve traction; widening the road surface at the more severe crests to improve sight distances for passing vehicles; and stabilizing channel crossings by constructing paved crossings with proper drainage structures to eliminate or reduce washouts.

Development of Department of Hawaiian Homelands (DHHL) Land Acquisition. Within an 82,354-ha (203,500-ac) land parcel set aside under the Hawaiian Homes Commission Act of 1921, the DHHL administers 22,734 ha (56,178 ac) of public land in Humuʻula and Piʻihonua, located on the southeastern slopes of Mauna Kea between 1,426 and 2,682 m (4,680 and 8,800 ft). When the general leases of the five homestead pastoral operations on this land expired in 2002, DHHL began planning the long-term land use and management of this parcel. Land uses considered include homesteading, commercial/service businesses, ecotourism, forestry, ranching, farming, cinder quarrying, gorse control, and resource areas (State of Hawaiʻi 2004).

No future land uses have been approved at this time (State of Hawaiʻi 2004).

Saddle Road Improvements. Saddle Road is subject to serious traffic congestion when military convoys are transporting ammunition or troops for training. A long-term highway construction project includes improvements and modifications to the Saddle Road between the Hilo side and Kona side of the island of Hawaiʻi. Approximately 78 km (48.5 mi) of road will be modernized to meet American Association of State Highway and Transportation Officials standards. Saddle Road, constructed in 1942, does not meet current design standards for roadways. It is the only access road to the Mauna Kea Access Road and the Astronomy Precinct and education facilities, the Army's Pōhakuloa Training Area, Waikiʻi Ranch, Kilohana Girl Scout Camp, Mauna Kea Station Recreation Area, and major hunting areas. A combined Federal/State EIS was completed in 1999 (USACE 2003). Construction has begun, but the implementation schedule and completion date for this project are not known.

PROJECTS NOT CONSIDERED FURTHER FOR MAUNA KEA

There are several projects that were never targeted for development on Mauna Kea, or were conceptually contemplated, but are not being considered further. These projects are discussed below.

Advanced Technology Solar Telescope. The Advanced Technology Solar Telescope, a project to help understand and predict changes in the Earth's climate and the solar-terrestrial environment (UH IfA 2003b), is not and has never been planned for the Mauna Kea Science Reserve (UH IfA 2004d).

Solar System Exploration Telescope. The Solar System Exploration Telescope was envisioned as a replacement for NASA's IRTF Telescope. It would be used to study the origin of our solar system by measuring the size and composition of objects beyond the orbit of Pluto and also could be used to study asteroids that come close to Earth, older solar systems around nearby stars, and the formation of new solar systems around very young stars (UH IfA 2001c). The project is no longer being pursued at this time (UH IfA 2004d).

National Planetary Telescope (NPT). This is the same concept as the Solar System Exploration Telescope discussed above. No further consideration is being given to the project at this time (UH IfA 2004d).

New Optical/Infrared Interferometer Array Site. The 2000 MKSR Master Plan (UH 2000b) addressed a potential plan for a new optical/infrared interferometer array within the next 20 years. This project would require a major Master Plan Amendment to gain approval for further planning. This amendment would require planning analysis, visual impact analysis, preparation of an EIS, and final review by the UH Board of Regents (UH 2000b). This project is not reasonably foreseeable at this time (UH IfA 2004f).

New Conventional Optical/Infrared Telescope. The final Master Plan included a provision to locate a conventional-size optical/infrared telescope at a new site in an area north of the summit ridge, with the intention to use this site only if a suitable summit ridge site was not available through recycling. Currently, the scope of future development of new facilities is significantly less than the Master Plan anticipated, and it is expected that summit ridge sites will be available through recycling for any new projects of this size. Therefore, it does not appear reasonably foreseeable that a telescope will be located at a new site north of the summit ridge.

CUMULATIVE IMPACTS

4.2.3 Cultural Resources

4.2.3.1 ROI for Cultural Resources

Cultural resources include historic and archaeological properties, and traditional cultural practices. The ROI for evaluating cumulative impacts on cultural resources includes the entire mountain from the Saddle to the summit, incorporating all areas of the mountain above approximately the 1,830-m (6,000-ft) elevation, which Native Hawaiians have identified as lands with very special traditional spiritual importance. The time frame in this case begins with the pre-Contact period. Table 4-10 outlines the history of Mauna Kea.

Mauna Kea has always been considered an integrated whole, a sacred place, in Hawaiian legend and history. Traditionally, Hawaiians visited the mountain's lower slopes to collect forest products, but the upper slopes and summit were visited only rarely by specialists such as cultural

TABLE 4-10. HISTORY OF MAUNA KEA

Year (C.E.)	Event
400–800	Pioneer Polynesian settlement.
1100–1800	Radiocarbon dates from adze quarry sites document Native Hawaiian use of quarries.
ca. 1600	Districts of Hāmākua and Hilo, including Mauna Kea summit, established during reign of ‘Umi a Liloa.
1778–79	Cook documents views of Mauna Kea and Hāmākua slopes.
1792–93	Capt. Vancouver gives cattle to Kamehameha I, who lets them graze around Mauna Kea and bans their killing for 10 years.
1823	William Ellis circles the island; his journal describes Mauna Kea and documents native traditions; Joseph Goodrich, with the Ellis party, visits the summit and finds a cairn.
1823–25	Journal of C.S. Stewart describes Mauna Kea.
1830	Hiram Bingham visits Mauna Kea with Kauikeaouli (Kamehameha III); describes Waiau and mountain. Hiram Bingham documents excursion of King Kamehameha III from Waimea to Mauna Kea.
1834	Dr. David Douglas traverses Mauna Kea.
1840	Charles Wilkes, Commander of U.S. Exploring Expedition, visits summit; Wilkes describes wild cattle at summit, well above the forests.
1841	William Richards documents Native Hawaiian astronomy and navigation; provides Hawaiian names for major plants.
1855–1868	Charles de Varigny, Secretary of French Consulate, visits Mauna Kea twice; describes in letters geese, wild cattle, boars, stray dogs, and plains stripped of *ohelo* berries by animals. Silverswords discovered at summit.
1862+	Boundary Commission Surveys: *ahupua‘a* boundary at summit recorded by Wiltse in 1862 is eventually changed, changing lands where various *pu‘u* and cultural features are located.
1870s–1880s	Boundary Commission hears Native Hawaiian testimonies concerning traditional uses of areas on Mauna Kea, establishes *ahupua‘a* boundaries for all the islands. Hawai‘i-born Curtis J. Lyons surveys Mauna Kea summit and surrounding areas.
1873	Isabella Bird traverses the saddle and describes Mauna Kea.
1882	Joseph S. Emerson surveys Kona, Kohala, and Puna, describes areas (other than Mauna Kea), describes and sketches the mountain.
1883	Queen Emma ascends the Summit.
1886	Humu‘ula Sheep Station established.
1889–1891	E.D. Baldwin maps summit and near-summit areas.
1892	W.D. Alexander, Surveyor General, follows wagon road from Waimea to Mauna Kea, climbs the mountain, describes Waiau and the summit, records traditional practice of burial on the summit plateau.
1903	Hawai‘i forest reserve system established to protect forests against fire and grazing — inspired by fires in Hāmākua.

TABLE 4-10. HISTORY OF MAUNA KEA (CONTINUED)

Year (C.E.)	Event
1930s	Civilian Conservation Corps plants tree and constructs horse and truck trails; vehicle trail around Mauna Kea at 7,000 feet elevation completed in 1935 – 167 miles in 12 hours 55 minutes.
1935 – 1936	Fence constructed around Mauna Kea Forest Reserve as sheep and goat exclosure; more than 40,000 sheep and goats exterminated within the exclosure.
1936, 1939	L.W. Bryan and the Civilian Conservation Corps build stone cabins for visitors' use at Hale Pōhaku.
1942 – 1945	Camps at Pōhakuloa established for U.S. Army and Marines combat training.
1943	Construction of Saddle Road.
1949	Paving of Saddle Road completed.
1956	Pōhakuloa Training Area created in 1956 as a U.S. Army installation.
1964	First road to the summit of Mauna Kea is bulldozed to facilitate astronomy development; NASA funds 12.5-in site-testing telescope.
1968	Air Force builds a 24-in telescope.
1970	UH completes 88-in telescope; Lowell Observatory builds a 24-in planetary patrol telescope on the summit ridge.
1974	NASA funds 3-m infrared telescope on Mauna Kea.
1979	IRTF, CHFT, UKIRT dedicated
1983	MKSR Development Plan adopted
1986	Caltech Submillimeter Observatory dedicated on Mauna Kea.
1987	James Clerk Maxwell submillimeter telescope dedicated.
1989	National Science Foundation funds Gemini North 8-meter Telescope on the site of the planetary Patrol observatory24-inch telescope on Mauna Kea.
1991	Keck I Telescope dedicated on Mauna Kea.
1992	Keck II Telescope site work begins;Very Long Baseline Array built, and site work begins for the 8.3-m Subaru, formerly know as Japan National Large Telescope.
1996	Keck II Telescope dedicated.
2000	UH Master Plan for MKSR approved.
2001	NASA proposes 2-meter class telescopes around Keck I and II Telescopes.
2002	Draft EA compiled for interferometer development; Submillimeter Array completed.
2004	EIS public meetings for interferometer development.

practitioners. The upper slopes on the south side contain a quarry where Hawaiians obtained material for use in manufacturing stone tools; the summit plateau above contains numerous shrines, evidence of pre-Contact ritual activities. The summit itself was regarded as a sacred landscape; no pre-Contact sites have been found in the summit area.

The primary projects considered in this evaluation include past, present, and reasonably foreseeable future astronomy-related projects; end of lease; past, present, and reasonably foreseeable future non-astronomy activities; tourism; recreational use; and closing of the jeep trail at Puʻu Poliʻahu.

4.2.3.2 Impacts of Past and Present Activities on Cultural Resources

Pre-Contact Impacts. Hawaiians, according to the archaeological evidence, began using the upland areas comprising the Saddle and the slopes of Mauna Kea in the 12th or early 13th century (Athens and Kaschko 1989; Reinman and Schilz 1994). In the forested areas on Mauna Kea Hawaiians collected bird feathers from honeycreepers to make cloaks and helmets, captured dark-rumped petrel nestlings, hunted Hawaiian geese and ducks, quarried basalt and volcanic glass for stone tools, and harvested *koa* (for canoe hulls), *ʻōhia*, *māmane*, and other woods. Foot trails were created to access these areas and to provide paths across the island. Some Hawaiians began journeying to the summit, constructing shrines of upright stones on the summit plateau and burying the bones of their ancestors in the cinder cones (McCoy 1999; Maly 1999). They discovered and began to quarry the hard, dense, fine grained volcanic rock found near the summit along an escarpment below Puʻu Waiau. Over a period of more than 500 years, craftsmen worked the quarry for stone to make adzes and other tools, leaving behind remains of numerous workshops and large piles of stone flake debris (McCoy 1990). Except for the activities at the quarry, the pre-Contact Native Hawaiian uses of Mauna Kea were generally on a small scale, without long-lasting adverse effects, resulting in a minimal impact to the mountain landscape.

Post-Contact Impacts. Contact with the Western world beginning with the arrival of Captain Cook in the islands in 1778 significantly altered the nature and intensity of the impacts on Mauna Kea.

The introduction of cattle and sheep in 1793 had devastating effects on the native vegetation of Mauna Kea over the next two centuries, severely affecting resources used by Hawaiians. The presence of large numbers of cattle and sheep on the mountain led to the near-disappearance of the silversword and the native *māmane* forests and grasslands as well as the loss of several native bird species.

Other avian species of cultural important to the Hawaiians, such as the *nēnē*, dark-rumped petrel, and *palila* became rare and endangered. The effects of grazing by feral animals and the development of large cattle and sheep ranches are discussed more fully in the Preface.

In the early years after Contact, visits by Native Hawaiians to the summit decreased greatly and few foreigners made their way to the summit. Later in the 19th century foreigners visited the mountain in ever-increasing numbers.

Trails worn by horses and humans had minimal impact on the mountain. Cart tracks were built in the late 19th century, followed by roads in the 1930s and 1940s, including one by the late 1930s that circled the mountain, as recorded by L.W. Bryan (Bryan 1921-1984).

The Saddle Road, built to provide access to the military training area at Pōhakuloa during World War II, was paved after the war, linking Hilo with Waimea. Along with the later paving of the road to Hale Pōhaku, this considerably eased access to Mauna Kea. The first road to the summit (sometimes referred to as the jeep trail) was cut in 1964, allowing development of the observatories, which began the same year. With respect to cultural resources, the easier access has had both adverse and beneficial effects. The road made possible the construction of the telescopes on the summit and grading for these altered the natural landscape of the spiritually important summit cones. The presence of larger numbers of visitors, some engaged in off-road recreational activities, increased the potential for disturbance to cultural resources. On the other hand, the roads have also facilitated access to the summit by cultural practitioners and allowed Native Hawaiians and scientists easier access to identify, record, and propose measures to protect cultural resources and culturally important natural resources.

Archaeological surveys conducted during the development of observatories on Mauna Kea include a reconnaissance survey of the Astronomy Precinct and adjacent areas in 1982 (McCoy 1982a; McCoy 1982b) (see Figure 3-1). These surveys, and more recent ones in 1995 and 1997 (McCoy 1999), identified 93 archaeological sites, mostly shrines within the MKSR. Surface sites found during surveys in the vicinity of development projects have been flagged and protected during construction. However, in most cases, monitoring during construction to identify possible subsurface cultural deposits or human burials was not undertaken. Also, because traditional cultural properties in the summit region had not been defined before 1999, little consideration was given to impacts on these properties. Thus, development within the Astronomy Precinct may have damaged subsurface cultural resources and has altered the appearance of the Kūkahauʻula traditional cultural property, interfered with views to and from the summit, and affected traditional cultural uses and practices.

Since cutting of the jeep trail and installation of the first telescope on Mauna Kea in 1964, cultural resources have substantially been altered. Past impacts include construction of several telescopes near or on the slopes of cinder cones that make up what the SHPD now recognizes as the historic property of Kūkahauʻula. This is spiritually the most important area of the mountain in Native Hawaiian tradition and remains the focus of cultural practices.

The construction of the Keck, Subaru, Gemini North, and NASA Infrared Telescopes each resulted in the movement of more than 7,646 m^3 (10,000 yd^3) of earth; both cutting and filling altered the appearance of the summit area. Grading and filling for the Keck Telescopes leveled approximately 1.1 ha (2.8 ac) and cut as far as 11 m (35 ft) below the surface on the slope of one summit cone, Puʻu Hauʻoki. The presence of these telescopes within the summit area continues to affect the performance of cultural practices. Nevertheless, the mountain retains a very rich traditional history with many archaeological sites, undoubtedly including some that have yet to be discovered.

In summary, past and present activities on Mauna Kea have substantially and adversely impacted cultural resources.

4.2.3.3 Impacts of Reasonably Foreseeable Future Activities on Cultural Resources

Future activities on the summit of Mauna Kea would continue the substantial adverse impact on cultural resources. No area at or near the summit is assumed to be devoid of archaeological properties, including the slopes surrounding the *puʻu,* which can be indirectly affected by development on the *puʻu*. Grading and removal of earth for new structures or roads, infrastructural redevelopment, or other observatory projects could adversely affect these resources. Further development could interfere with views and access to and from the summit or could hinder other cultural uses of the general area. If an archaeological site is discovered during excavation, grading, or other activities before or during construction of future projects, mitigation measures such as those outlined in the Section 106 MOA (Appendix B) would help reduce the cultural impact.

Mitigation measures, such as the following, would reduce adverse effects.

- Archaeological surveys preceding any future ground-modifying work (including work on associated staging areas).
- Monitoring of ground-modifying activities by a qualified archaeologist.
- Consultation with representatives from the Native Hawaiian community before construction activities begin for on-site assessment of any area to be disturbed.
- Cultural monitoring during on-site construction and installation.
- Specification of procedures if a burial site is identified during excavation.

Even with such mitigation measures, some reasonably foreseeable future projects will have an unavoidable adverse impact on cultural resources. In particular, projects located in previously undisturbed areas have greater potential for altering topographical contours and disturbing archaeological sites and human burials. For a project such as TMT, which is both extremely large and proposed for a previously undisturbed site, adverse cultural resource impact is likely.

For reasonably foreseeable astronomy projects, it is assumed that appropriate mitigation measures will be implemented. At a minimum, on-site construction, installation, and operation will adhere to the stipulations established in the 2000 Master Plan for the MKSR. Project participants and construction contractors and their personnel will adhere to HRS 343 and conditions imposed under the CDUP process. Further, when Federal funds are involved, the NEPA process will be followed. In addition, all future astronomy projects are assumed to occur within the Astronomy Precinct, which was designed to avoid historic sites, preserve view corridors, and maintain the integrity and aesthetics of the cultural landscape as far as possible.Foot traffic within the MKSR may increase as future development, such as improvements to the Saddle Road, facilitates access to and within the summit region, possibly causing further disturbance of cultural sites in this region. Ranger monitoring and educational programs at the VIS are expected to help offset this potential cumulative impact to archaeological resources.

Even with all the mitigation measures discussed above, from a cumulative perspective, the potential impacts of reasonably foreseeable future activities are anticipated to be adverse and substantial.

4.2.3.4 Cumulative Impact Summary

Mauna Kea has a rich traditional history and many archaeological sites, including some that have yet to be discovered. Before 1982, only limited cultural and archaeological surveys were conducted in preparation for developments on the mountain. Thus, it is not known whether development of the Astronomy Precinct beginning in 1964 has damaged subsurface cultural resources. However, such development has clearly altered the appearance of the Kūkahau‘ula traditional cultural property, interfered with views to and from the summit, and affected traditional cultural uses and practices. Grading and removal of earth for new structures, redeveloped structures, roads, and other astronomy projects could further affect these resources adversely. Following appropriate mitigation measures, such as those described in the NHPA Section 106 MOA, and developing project-specific mitigation measures for future activities would reduce adverse effects.

Mitigation measures developed for the Outrigger Telescopes Project and made part of the Section 106 MOA would minimize the impact of the Outrigger Telescopes Project and could potentially provide beneficial impacts, including community outreach and cultural stewardship.

From a cumulative perspective, the impact of past, present, and reasonably foreseeable future activities on cultural resources on Mauna Kea is substantial and adverse. The addition of the Outrigger Telescopes would have a small incremental impact.

4.2.4 Biological Resources and Threatened and Endangered Species

4.2.4.1 ROI for Biological Resources and Threatened and Endangered Species

For the purposes of this analysis, the ROI extends from the summit of Mauna Kea down to the elevation of the intersection of the Mauna Kea Access Road and Saddle Road. The potential impacts to the biological resources are primarily in the four ecological zones described in Section 3.1.3. The major activities considered in this evaluation include paving the Mauna Kea Access Road; past, present, and reasonably foreseeable future astronomy-related projects; and tourism and recreational use.

4.2.4.2 Impacts of Past and Present Activities on Biological Resources and Threatened and Endangered Species

The flora and fauna of the four ecological zones were described in Sections 3.1.3.1 and 3.1.3.2.

Summit Area Cinder Cones and *Area Below the Summit Cinder Cones*

Flora. According to historic reports, no vascular plants were observed on Mauna Kea above 4,115 m (13,500 ft) before 1940 (Hartt and Neal 1940). Lichens inhabiting rocks scattered over the surface of the cinders were the only vegetation seen on the summit cinder cones (Neal 1939, Hartt and Neal 1940). This condition has remained largely unchanged to the present. Habitats for lichens, mosses, and ferns below the summit cinder cones are widespread. Less than one percent has been disturbed or displaced by astronomy-related activities. The impacts of past and present activities on the flora of the *Summit Area Cinder Cones* and the *Area Below the Summit Cinder Cones* has been small and not significant.

Fauna. Eleven species of arthropods are believed to be the only indigenous animals on Mauna Kea above 3,566-m (11,700-ft). Quantitative information has been collected for only one of these species, the Wēkiu bug, a candidate for listing under the Endangered Species Act. Its population was first assessed in 1982. Wēkiu bugs were found to be very abundant on the summit cinder cones (Howarth and Stone 1982). In a second assessment in 1997/98 trap capture rates were found to have declined by 99.7 percent in comparable areas (Howarth and others 1999). In that study, trap capture rates were highest on cinder slopes presumed to have been previously disturbed by observatory construction. The cause of the decline is unknown. Hypotheses include changing weather patterns, habitat disturbance such as that caused by observatory construction and recreational activities, introduction of harmful alien species, and long-term population cycles (Howarth and others 1999). More recent sampling has found that Wēkiu bug trap capture rates have substantially increased since 1998, in some areas returning to rates similar to those measured in 1982 (Pacific Analytics, LLC 2003b). Observational data collected during the 1997/98 assessment also suggested the lycosid spider population was comparable to what it was in 1982.

There have been several studies of the extent of Wēkiu bug habitat. An initial study in 1982 identified 232 ha (573 ac) of Wēkiu bug habitat, all above the 12,800 ft elevation (Howarth and Stone 1982) (see Table 4-11). This is a lower limit to the total Wēkiu bug habitat at that time, since it is very likely that Wēkiu bugs occurred elsewhere in unsampled areas. The 1997/98 study (Howarth and others 1999) found Wēkiu bugs only above the 13,400 ft elevation level, corresponding to a total area of 120 ha (300 ac). Later studies identified 579 ha (1,434 ac) of Wēkiu bug habitat extending down to the 11,715 ft level (Polhemus 2001; Pacific Analytics, LLC 2001; Englund and others 2002) (see Table 4-12). Since these studies, Wēkiu bug capture rates in some areas have nearly returned to the levels measured in 1982, which were the highest levels measured in any of these studies. It is therefore reasonable to infer that the 579 ha (1,434 ac) identified in the 2001-2002 studies is a lower limit to the current amount of Wēkiu bug habitat.

It is possible to set an upper limit to the percentage of this habitat that has been displaced or disturbed by astronomy-related activities. Astronomy-related activities (observatories, roads, and parking areas) above the 3,571 m (11,715 ft) elevation, the lowest elevation at which Wēkiu bugs have been found, have displaced about 17 ha (41 ac) and disturbed about an additional 8.5-ha (20.5-ac) of adjacent land. This 25.5 ha (63 ac) of displaced or disturbed land is 4.4 percent of the 579 ha that is estimated to be the lower limit to current Wēkiu bug habitat. The actual percentage of Wēkiu bug habitat displaced or disturbed by astronomy-related activities is likely to be lower than 4.4 percent for the following reasons: (1) 579 ha is a lower limit estimate of the current amount of Wēkiu bug habitat; (2) some of the 8.5 ha of disturbed area are currently the sites of the highest Wēkiu bug capture rates; and (3) only a portion of the 25.5 ha displaced or disturbed by astronomy-related activities was originally Wēkiu bug habitat. Thus, 4.4 percent is an upper limit to the fraction of Wēkiu bug habitat that has been directly and adversely affected by astronomy-related activities.

Although capture rates in some areas have nearly returned to the relatively high levels measured in 1982, this is not uniformly the case. On Pu‘u Wēkiu, where the highest capture rates (about 45 bugs/trap/3 days) were measured in 1982, current capture rates are relatively low (about 12 bugs/trap/3 days) (Pacific Analytics, LLC 2003). These areas are unaffected by astronomy development. However, other human activities (e.g., hiking and foot traffic) or natural phenomena (e.g., changing weather patterns) could be at least in part responsible for the low current capture rates.

The earlier studies of Wēkiu bugs had at least a small adverse impact on Wēkiu bug populations. The 1982 (Howarth and Stone 1982) and 2001 (Polhemus 2001) studies used baited ethylene-glycol traps to assess the populations. These traps caused 100 percent mortality of all insects captured in them. During the 1982 Arthropod

TABLE 4-11. WĒKIU BUG HABITAT DISPLACEMENT[a]

Habitat Population Density	Study Area Size of Wēkiu Bug Habitat	Area of Habitat Displaced by Observatories	Area of Habitat Displaced by Roads	Area of Habitat Displaced by Other
High	63 ha (156 ac)	2.4 ha (6 ac)	0.6 ha (1.6 ac)	0.2 ha (0.4 ac)
Moderate	120 ha (297 ac)	0 ha (0 ac)	0.4 ha (1 ac)	0 ha (0 ac)
Low	49 ha (120 ac)	1.5 ha (4 ac)	2 ha (4.4 ac)	0 ha (0 ac)
TOTAL	232 ha (573 ac)	4 ha (10 ac)	3 ha (7 ac)	0.2 ha (0.4 ac)

a. Wēkiu bug habitat in the 1982 study area on Mauna Kea and the area displaced by astronomy-related activities (Howarth and Stone 1982; R.M. Towill Corp 1997).

TABLE 4-12. WĒKIU BUG KNOWN SITES

Cinder Cone Habitat[a]	Area
Pu‘u Wēkiu, Hau‘oki, Kea	184 ha (452 ac)
Pu‘u Poliahu	95 ha (234 ac)
Pu‘u Haukea	51 ha (125 ac)
Pu‘u Mahoe	79 ha (196 ac)
Pu‘u Ala	59 ha (147 ac)
Pu‘u Poepoe	26 ha (64 ac)
Pu‘u Makanaka	75 ha (186 ac)
Unnamed Pu‘u near VLBA	12 ha (30 ac)
TOTAL	579 ha (1,434 ac)

a. Cinder cone habitat on Mauna Kea where Wēkiu bugs have been found (Wolfe and others 1997; Howarth and Stone 1982; Howarth and others 1999; Polhemus 2001; Pacific Analytics, LLC 2002a–2003d; Englund and others 2002).

Assessment more than 40,000 Wēkiu bugs were captured and killed. Conventional entomological wisdom holds that sampling does not impact insect populations. On the other hand, New (1984) stated that fragmented (geographically-isolated) populations can be vulnerable, and excessive collecting can sometimes tip the balance towards extinction. Since the 1982 study, live traps have been developed that enable sampling of the Wēkiu bug without causing high mortality rates.

Wēkiu bug populations may also have been affected by the introduction of alien species. These invasive species can potentially eliminate native arthropods from their summit habitats. In 1997, an alien species of hunting spider (family Clubionidae) was found on Pu‘u Wēkiu (Howarth and others 1999). This species was thought to be a potential resident of the summit, but so few have been collected (Pacific Analytics, LLC 2002a – 2003d) that definitive conclusions can not be made. A non-indigenous sheetweb spider (Family Linyphiidae) has also been observed on the *Summit Area Cinder Cones* (Howarth and others 1999). Both species have the ability to capture and kill Wēkiu bugs and therefore have the potential to impact Wēkiu bug populations. The means of introduction of these two spiders are unknown. They may have arrived at the summit during construction of the observatories, from tourists visiting the mountain, or by other means. Data about the impact of these spiders are not available and concerns persist that these spiders may be having an adverse impact on Wēkiu bugs.

The only other harmful invasive alien arthropod species that have been identified from the *Summit Area Cinder Cones* are several species of parasitic and predaceous wasps (Howarth and Stone 1982; Montgomery 1988; Howarth and others 1999; Pacific Analytics, LLC 2002a – 2003d; Englund and others 2002). These wasps are carried by winds to the summit area from surrounding lowlands, and could potentially prey on or parasitize native resident arthropods. None of these wasps are thought to be residents of the summit or the *area below the summit cones* on Mauna Kea and therefore do not currently present a serious threat to native resident arthropods of the MKSR.

Some native resident species, such as the Wēkiu bug and lycosid wolf spider, depend upon aeolian (wind-blown) drift as food. It has been suggested that observatory domes and other buildings have altered the natural deposition patterns of drift. There is no evidence that this is the case, since Wēkiu bugs and lycosid wolf spiders continue to live on the cinder slopes downwind of the W.M. Keck Observatory site.

Spills of hazardous materials can also affect Wēkiu bugs and their habitat. Early biotic surveys of the Astronomy Precinct mentioned hazardous materials spills that occurred in Wēkiu bug habitat (Howarth and Stone 1982; Smith and others 1982). The principal spill (which affected about 18 m^2 (194 ft^2)) appears to have occurred beneath the 850 kW mobile generator (which powered all of the existing observatories at that time) at approximately the 4,023 m (13,200 ft) elevation level in the construction staging area near Puʻu Haukea. In 1996 about 227 to 246 l (60 to 65 gal) of ethylene glycol were spilled at the Subaru Observatory. This spill was cleaned up and the contaminated cinder transferred to an authorized disposal site. In March 2004 between 76 and 114 l (20 and 30 gal) of ethylene glycol were spilled inside the W.M. Keck Observatory. Some of the ethylene glycol escaped under the exterior door and flowed into the cinder parking area outside. This spill was immediately cleaned up and the contaminated cinder transferred to an authorized disposal site. These spills were limited to small areas and cleaned up promptly and therefore had little impact on the Wēkiu bug population.

Concerns have also been expressed that wastewater from septic systems may impact Wēkiu bugs. Cesspools and seepage pits direct wastewater into the cinder several feet below the zone of activity of Wēkiu bugs and other arthropods. Wastewater from these sources is not expected to have an adverse effect on the natural ecosystem when the waste systems are working properly. In 1998, a sewage spill was observed in Wēkiu bug habitat in Puʻu Hauʻoki crater. About 8-l (2-gal) of sewage leaked from an incorrectly installed septic line onto the cinder and snow. The contaminated cinder and snow were removed soon after the spill was reported and the leak repaired (Subaru 1998). While this spill was relatively minor, this type of spill can cause habitat damage, filling interstitial spaces or disturbing cinder substrate structure that could take years to recover. No other sewage spills have been reported, and no direct effects of properly installed septic systems on Wēkiu bugs and other arthropods have been observed.

Scattered trash can also affect Wēkiu bugs. The 1982 botanical survey of Mauna Kea (Smith and others 1982) reported a considerable amount of rubbish scattered over the mountaintop. Trash can shade out plants, stunting their growth, and prevent aeolian deposition of food resources for the Wēkiu bugs and lycosid wolf spiders. UH responded to this concern in the 1999 MKSR Master Plan EIS by accepting responsibility for trash on the mountain within the Science Reserve (UH 1999). Since then trash has been conscientiously collected by Mauna Kea Support Services and observatory personnel, and is now rarely seen within MKSR.

Water runoff and sediment deposition along roads and drainage ditches has the potential to erode and cover habitat of Wēkiu bugs, lycosid spiders, and other summit-resident arthropods and plants in some places. Runoff and sediment are carefully controlled using swales, drains, and catch basins and only during extreme precipitation would erosion be expected to be a problem. As discussed previously, the summit region experiences limited rainfall and only small amounts of surface water runoff, and there are no impacts from water runoff on natural habitats on the *Summit Area Cinder Cones* or the area below them.

Trap capture rates of the other summit resident native arthropod species on Mauna Kea have not been measured or analyzed. Impacts to these other species and their habitats are probably similar to those experienced by Wēkiu bugs and lycosid spiders. However, since these other species are relatively widely distributed, the impacts in these two ecological zones are relatively small and of no significance.

No birds or other wildlife are known to nest or forage on the *Summit Area Cinder Cones* or the area below them.

In summary, there has been a substantial adverse impact on Wēkiu bugs in at least part (e.g., Pu‘u Wēkiu) of the two upper ecological zones. However, there is not enough information to determine the contribution of human activities to that impact. In particular, there is not enough information to determine the magnitude or significance of past and present astronomy-related activities on the Wēkiu bug and its habitat. There have been no significant impacts on other biological resources in these two zones.

Silversword/Alpine Shrub Zone

Flora and Fauna. About six miles of dirt road have been installed in the *Silversword/Alpine Shrub Zone*. This represents less than one percent of the entire range of silversword habitat on Mauna Kea. Based on the records of early naturalists, silverswords grew in abundance and were the dominant plants of the alpine ecosystem (Robichaux and others 2000). In the late 1700’s, sheep, cattle, and other ungulates were introduced to Hawai‘i, and silversword populations declined as the ungulates established populations on Mauna Kea. The small natural population of silverswords that persists on Mauna Kea now contains only 42 plants (Robichaux and others 2000). This population is more than 4 km (2.5 m) away from the nearest observatories. A court ordered ungulate removal program has reduced damage to silverswords and the chances for recovery have increased. Observatory construction is not believed to have had an impact on this species (USFWS

2004). This species will continue to receive protection through its Federal listing as an endangered species.

The other biological resources found in the *Silversword/Alpine Shrub Zone* are not unique to the zone and are found elsewhere on Mauna Kea. Other than the decline in the silversword resulting from the introduction of cattle, sheep, and other ungulates, there has been no significant impact of past and present activities on the biological resources in the *Silversword/Alpine Shrub Zone.*

Māmane/Subalpine Forest Zone

Flora. The *Māmane/Subalpine Forest Zone*, discussed in Section 3.1.3.4, extends from Saddle Road to about 2,804 m (9,200 ft). The open-canopied forest predominantly comprises *māmane* trees (*Sophora chrysophylla*), and is home to the federally listed endangered bird, *palila* (*Loxiodes bailleui*). Early 20th century expeditions noted the already degraded condition of the subalpine forest due to wild sheep and cattle grazing (Hartt and Neal 1940). Over a century and a half of grazing by feral ungulates resulted in increased evapo-transporation, causing a change in the understory conditions at Hale Pōhaku from moderately moist to deficient in moisture (Garrish 1979). Ungulates run away when humans are present, and human activity at Hale Pōhaku has brought a decline in feral ungulates there. This has consequently allowed the *māmane/naio* forest surrounding the mid-elevation support facilities to regenerate (Garrish 1979). Other than the substantial impacts resulting from grazing ungulates noted above, the impacts of past and present activities on the flora in the *Māmane/Subalpine Forest Zone* have been small.

Fauna. *Palila* were once found in the *māmane/naio* forests on west and southwest Mauna Loa and Mauna Kea. They currently occur only in the *māmane/naio* forest of Mauna Kea (Scott and others 1986) where there are available food resources, suitable nesting habitat, fewer ants, and fewer disturbances by humans. *Palila* reach their highest densities near Puʻu Laʻau on the western slopes of Mauna Kea. The population has fluctuated since 1975 and ecological research is ongoing. This bird is protected by its Federal listing as endangered.

Operations at Hale Pōhaku occupy only a small part of the critical habitat and are not considered a threat to the bird (USFWS 1979). NASA has requested an updated opinion regarding activities at Hale Pōhaku and their potential impact on *palila*. Dr. Paul Banko, principal investigator for the U.S. Geological Survey, Biological Resources Division *palila* research team was recently quoted as saying about *palila* that "In the last four to five years the population is stabilizing, even increasing a bit" (Smith 2003).

More than two hundred species of arthropods have been found to be associated with the *Māmane/Subalpine Forest Zone* (Gagne and Montgomery 1988; USDOT 1997). None of the species are on Federal or State lists of threatened and endangered species. There have been no measured impacts to the arthropod fauna of the *Māmane/Subalpine Forest Zone.*

Summary of Past and Present Activities on Biological Resources and Threatened and Endangered Species

"Silversword and *palila* have been substantially impacted from overgrazing of the *Silversword/Alpine Shrub Zone* and the*Māmane/Subalpine Forest Zone* by cattle, sheep, and feral ungulates. There have been small but no significant impacts on the flora in the *Summit Area Cinder Cones* and the *Area Below the Summit*

Cinder Cones ecological zones by past and present activities on Mauna Kea. Since 1982 there was a substantial adverse impact on Wēkiu bugs in at least part (e.g., Pu‘u Wēkiu) of the two upper ecological zones. However, there is not enough information to determine the contribution of human activities to that impact. In particular, there is not enough information to determine the magnitude or significance of past and present astronomy-related activities on the Wēkiu bug and its habitat. There have been small but no significant impacts to other fauna in the four ecological zones by past and present activities on Mauna Kea."

4.2.4.3 Impacts of Reasonably Foreseeable Future Activities on Biological Resources and Threatened and Endangered Species

The analysis of reasonably foreseeable future activities on the biological resources within the ROI is based on the information about these projects contained in Section 4.2.2. The impacts of these projects are discussed in the context of the four ecological zones described in Section 3.1.3. Astronomy sponsored studies on Mauna Kea have brought attention to the sensitive nature of the biological resources that live there. In 2000, the University of Hawai‘i created the Office of Mauna Kea Management, and gave it comprehensive management authority to protect the sustainability of Mauna Kea's resources (UH 2000b). That Office is developing guidelines and procedures for protecting these resources. Without these guidelines and the protection they would bring about, there is a potential for substantial and significant impacts on the biological resources of Mauna Kea. In this analysis, estimates of the intensity of impacts from reasonably foreseeable future activities are made with the assumption that OMKM guidelines, and review by the DLNR through the Conservation District Use permitting process, will require species and habitat protection for all future development.

Summit Area Cinder Cones and the *Area Below the Summit Cinder Cones*

Flora. It has been estimated that up to 4 ha (10 ac) of non-cinder habitat could be disturbed as a result of the grading and construction for new observatories, and their support facilities and roadways (UH 1999). The proposed new facility areas are in habitats used by lichens, mosses, and ferns, and contain three special interest areas of high lichen concentrations (Smith and others 1982). UH/IfA is aware of the three special interest areas of high lichen concentrations and would position new observatory facilities carefully to avoid destruction of sensitive populations of lichens and ferns, thus impacts are expected to be small to moderate, and not significant. If built on the proposed northern plateau site, it is estimated that the TMT would cover up to 2-ha (5-ac) of lichen habitat and could potentially disturb the three areas of special interest. Without careful placement of the TMT, impacts could be substantial because many of the lichen species there have not been observed elsewhere within the MKSR. The SMA expansion would also displace lichen habitat, but its impact would be small if confined to the development of only a few small telescope pads.

Dust generated by reasonably foreseeable future astronomy development would have only small impact to nearby flora because dust control measures would be implemented. Without these measures, dust could: (1) cover rocks and make them unsuitable for colonization by lichens and mosses; (2) cover existing plants, depriving them of light needed to photosynthesize; or

(3) abrade the plants as it is blown by the wind (Sohmer and Smith 1982).

Disposing of excess excavated material would likely be carried out after consultations with OMKM. Potential impacts from appropriate disposal would be small.

In summary, habitat protection measures are likely to be required in Conservation District Use Permits for reasonably foreseeable future astronomy development, and this development is therefore likely to have only a small impact on the flora of the *Summit Area Cinder Cones* and the *Area Below the Summit Cinder Cones.*

Fauna. Reasonably foreseeable future astronomy facilities planned on the *Summit Area Cinder Cones*, such as the Testing and Site Monitoring and redevelopment of the UH 0.6-m (24-in) and 2.2-m (88-in) telescopes, would have small impacts on adjacent habitats. Redevelopment of the UH observatories, CFHT, IRTF, and UKIRT has a lower potential for impact on the Wēkiu bug than new observatory development t on the summit ridge. The implementation, in any redevelopment projects, of protection measures similar to those proposed for the Outrigger Telescopes (see Appendix D, Wēkiu Bug Mitigation Plan in this DEIS) would protect adjacent habitats from construction materials, waste, or dust migrating off-site; from equipment mobilization and staging; from contamination of cinder habitat with hazardous materials; and from introduction of invasive species.

It is likely that future scientific ecological studies would have a negligible to small impact on sensitive species such as the Wēkiu bug because the refinement of sampling methods has reduced mortality to about two percent. Scientists walking in habitat can disturb tephra cinders and crush them to dust-sized particles. When live-traps are used predominantly for all future Wēkiu bug studies, and care is taken to not disturb large areas of habitat when sampling, there would be a small and not significant impact from future scientific research.

The probability for fuel spills has been lessened because power is no longer generated at the summit. As long as any future spills of any hazardous materials were limited to small areas and cleaned up promptly, there would be little impact to the Wēkiu bug and other fauna.

Although reasonably foreseeable future development would take place in arthropod habitats in the *Area Below the Summit Cinder Cones*, the prominent species that live there, lycosid spiders and summit moths, are both widespread below the summit area (Howarth and others 1999), and are likely to experience only a small impact from future projects. The development of new sites in the *Area Below the Summit Cinder Cones* would have a no impact on Wēkiu bugs because the sites have only small patches of Wēkiu bug preferred habitat (Howarth and Stone 1982, Wolfe and others 1997).

Rules prohibiting off-road driving on the MKSR are enforced by rangers who frequently patrol the area. Thus, off-road vehicles would cause little damage to habitat and have no impacts on sensitive species. Visitors to the summit of Mauna Kea have the potential to impact natural resources. Walking off trails and collecting rock souvenirs can disturb Wēkiu bug habitat. Increased tourism, resulting from future development and use of the summit for recreation, may increase inadvertent disturbance to natural habitat. This manner of habitat disturbance could potentially have moderate to substantial impacts on Wēkiu bug populations.

In summary, appropriate protection of Wēkiu bug habitat would reduce the potential impacts to Wēkiu bugs and other resident species. Foreseeable future astronomy activities would have a potentially small to moderate impact on the nearby fauna, but other causes of habitat disturbance could potentially have moderate to substantial impacts.

Silversword/Alpine Shrub Zone

There are no reasonably foreseeable future projects in this zone. The potential for future impacts from traffic through this zone is small and not significant.

Māmane/Subalpine Forest Zone

Reasonably foreseeable future projects in this zone, such as the Visitors Information Station Expansion, completion of the Mauna Kea Access Road, Army Transformation, Remotely Operated Microwave Facility, Keanakolu Road Improvements, and Development of DHHL Land Acquisition are not expected to have a any impact on the flora and fauna within the ROI because the actions would occur outside the ROI, and because the amount of habitat disturbed within the ROI, if any, would be small compared to the amount available.

Summary of Reasonably Foreseeable Future Activities on Biological Resources and Threatened and Endangered Species.

Reasonably foreseeable future projects have small, but not significant impacts to the biological resources within the ROI. Almost all of these impacts would be prevented by appropriate protection measures similar to those outlined in the Wēkiu Bug Mitigation Plan if implemented. If protection measures are not implemented, there is a potential for substantial and significant impacts from reasonably foreseeable future projects on the biological resources of Mauna Kea.

4.2.4.4 Cumulative Impact Summary

There have been substantial impacts to biological resources, but the best available information does not always permit complete understanding of the causes of those impacts. The impact of past, present, and reasonably foreseeable future activities from all causes is likely to be small. The incremental impact of the Outrigger Telescopes Project is small and not significant. Further, on balance, the impact from the Outrigger Telescopes Project is likely to be beneficial to biological resources. Overall, considering past, present, and reasonably foreseeable future activities, the cumulative impact to biological resources is adverse and significant.

4.2.5 Hydrology, Water Quality, and Wastewater

4.2.5.1 ROI for Hydrology, Water Quality, and Wastewater

The ROI is the summit area and the potentially connected surface and subsurface flow paths. Surface runoff pathways are identifiable by surface topography. Subsurface flow paths— consisting of the nearly vertical downward travel through unsaturated lavas and lateral movement with groundwater— ultimately extend all the way to the island's shorelines.

4.2.5.2 Impacts of Past, Present, and Reasonably Foreseeable Future Activities on Hydrology, Water Quality, and Wastewater

The impacts of past and present activities on hydrology and water quality are reasonably represented by the impacts of the present 12 observatories at the summit and the support facilities at Hale Pōhaku. These impacts are considered and quantified in this section along with those of foreseeable future projects.

Basis for the Quantifying Cumulative Impacts. The following assumptions were used to quantify the cumulative impacts.

- The sites of all 12 observatories at the summit will continue to be used.
- The Outrigger Telescopes Project at the W.M. Keck Observatory will be implemented as proposed.
- The TMT will be constructed at a new site at the northwest plateau. Site preparation and facility construction would be initiated at some point after completion of the Outrigger Telescopes Project. The maximum construction workforce would be about 60 workers all of whom would temporarily reside at Hale Pōhaku. The finished footprint and rates of water use and wastewater generation during TMT operation would be similar to the existing W.M. Keck Observatory.
- The PanSTARRS project will be built at the site of the UH 2.2-m (88-in) Telescope. Its water use and wastewater generation would be similar to the average of the present Mauna Kea observatories which is about 150 gpd.
- Water would continue to be trucked to the summit and to Hale Pōhaku as it is now.
- The average water use by the observatories in 2003 is, as a first order approximation, representative of past, present, and future water use (except for the redevelopment and expansion described above). The 2003 water use rates are compiled in Table 4-13.
- Also as a first order approximation, all water trucked to the summit would become domestic wastewater with subsurface disposal. Wastewater treatment and disposal systems for new facilities would be similar to those in place for the existing observatories (see Table 4-14).
- As with present practice, all other wastewater (such as for mirror washing) would continue to be captured in containers and trucked down the mountain for treatment and disposal elsewhere.
- Future water use and wastewater disposal at Hale Pōhaku would increase in proportion to the estimated increase in water use at the summit.
- The unpaved 7.4-km (4.6-mi) long segment of the summit access road from just above Hale Pōhaku to 3,627-m (11,900-ft) elevation would ultimately be paved.
- Based on the foregoing assumptions and present rates of water use compiled in Table 4-13, the ultimate water use and wastewater disposal amounts at the summit and at Hale Pōhaku would be as shown in Table 4-15. These assumptions result in an estimated increase in water use and wastewater generation of about 25 percent.
- Projects will comply with all regulations, mitigation plans, and construction best management practices.
- With the exception of Wēkiu bug habitat restoration and monitoring, all reasonably foreseeable future projects, as appropriate to the given project, would implement environmental protection and mitigation measures similar to those proposed for the

TABLE 4-13. WATER USE AND WASTEWATER GENERATION

Location	Rate of Water Use and Wastewater Generation	
	At Present (gpd)[a]	Future (gpd)
At the Summit		
Existing Observatory Sites	1,780	1,815
New Sites	0	400
Total	1,780	2,215
At Hale Pōhaku	3,800	4,730

a. gpd = gallons per day.

TABLE 4-14. WASTEWATER GENERATION AND TREATMENT AND DISPOSAL SYSTEMS AT THE MAUNA KEA OBSERVATORIES

Name of Facility	Average Wastewater Flow Rate (gpd)	Treatment and Disposal System
W.M. Keck Observatory	399	4-kl (1,000-gal) septic and 4-m (12-ft) deep seepage pit
NASA Infrared Telescope Facility	50	5-kl (1,450-gal), two compartment septic tank and leach field (27 m (90 linear ft))
Canada-France-Hawaiʻi Telescope	295	Septic tank and leach field
Subaru Telescope	360	5-kl (1,250-gal) septic tank and two seepage pits
Gemini North Telescope	122	4-kl (1,000-gal) septic tank and 3-m (10-ft) deep seepage pit
University of Hawaiʻi Telescopes 0.6 m and 2.2 m (24 in and 7.2 ft)	115	9.5-kl (2,500-gal) septic tank and leach field
United Kingdom Infrared Telescope	111	4-kl (1,130-gal), two compartment septic tank and leach field (23 m (75 linear ft))
Caltech Submillimeter Telescope	65	2-m (7-ft) diameter, 3-m (10-ft) deep cesspool
James Clerk Maxwell Telescope	109	2-m (8-ft) diameter, 4-m (13-ft) deep cesspool
Submillimeter Array	118	4-kl (1,000-gal) septic tank and leach field (81 m (265 linear ft))
Very Long Baseline Array	31	2-m (7-ft) square-shaped, 3-m (10-ft) deep cesspool

1 gal = 0.0038 kl

1 m = 3.2808 ft

TABLE 4-15. WATER DELIVERIES TO THE SUMMIT OBSERVATORIES IN GALLONS PER MONTH, JANUARY THROUGH DECEMBER OF 2003

Month	UH	IRTF	UKIRT	CFHT	JCMT	CSO	KECK	NRAO	SUBARU	GEMINI	SMA	TOTAL
January	2,100	1,800	2,500	8,200	2,500	1,800	10,000	-	10,000	5,000	6,100	50,000
February	3,400	3,200	6,400	7,500	2,500	2,000	14,200	1,750	8,000	-	5,650	54,600
March	1,600	600	3,200	10,000	5,700	1,500	10,000	-	24,000	3,500	3,800	63,900
April	1,700	1,500	1,900	3,400	2,400	1,300	10,500	2,000	10,000	2,400	2,900	40,000
May	2,450	500	1,500	10,000	2,400	1,800	19,500	800	5,000	3,550	2,500	50,000
June	600	1,000	5,100	5,000	4,300	3,000	11,200	-	15,000	2,000	2,800	50,000
July	2,500	2,500	5,600	8,600	3,700	1,400	10,000	700	15,000	2,600	2,400	55,000
August	2,400	2,600	3,000	13,000	2,200	2,000	14,800	2,000	10,000	3,000	-	55,000
September	5,000	1,200	-	7,000	4,100	2,000	10,500	2,200	10,000	3,200	4,800	50,000
October	10,000	-	5,700	10,000	4,300	2,500	15,000	-	10,000	10,000	2,500	70,000
November	5,400	500	3,100	10,000	3,200	1,900	10,000	1,000	9,500	1,800	3,600	50,000
December	5,000	2,950	2,500	15,000	2,500	2,700	10,000	850	5,000	7,500	6,000	60,000
Total for the Year	42,150	18,350	40,500	107,700	39,800	23,900	145,700	11,300	131,500	44,550	43,050	648,500
Average (gpd)	115	50	111	295	109	65	399	31	360	122	118	1777

Note: The average wastewater flow rate is assumed to be equivalent to the average amount of water trucked to each observatory for the January through December 2003 period.

Outrigger Telescopes Project Wēkiu Bug Mitigation Plan.

Possible Hydrologic Impacts. As described in Section 4.1.4.2, there are two categories of possible hydrologic impacts to consider: changes to surface runoff; and impacts to groundwater due to subsurface wastewater disposal. Each of these is discussed in the sections following.

Possible Changes to Surface Runoff. Exclusive of the summit access road, the total area disturbed for the installation of the 12 existing observatories is approximately 7 ha (17 ac). This includes the impervious surfaces at each of the observatories (which amounts to less than 2 ha (4 ac)), adjacent and generally unpaved leveled areas, and access driveways. The 7-ha (17-ac) area distributed among the 12 observatories comprises about three percent of the 212-ha (525-ac) area of the Astronomy Precinct and less than 0.2 percent of the 4,452-ha (11,000-ac) MKSR. If a new site is developed for the TMT and expansion at existing sites occurs as assumed in Section 4.2.2, the estimated disturbed area would not likely exceed 10 ha (25 ac)— about 5 percent of the Astronomy Precinct and about 0.2 percent of the entire MKSR.

A thorough examination of all 12 observatory sites at the summit reveals a similar situation with regard to surface runoff as exists at W.M. Keck Observatory. Across all of the disturbed areas that surround the impermeable surfaces at each of the 12 observatories, strong winds have removed fine particles from the surface cinders, leaving behind a permeable layer of coarse sand and gravel-sized particles. At all 12 individual observatory sites, there is no evidence of surface runoff across these gravel surfaces; the capacity of this layer to absorb water has always been greater than the rate of precipitation. In other words, no surface runoff comes off these sites and runs down the slopes of the various volcanic cones on which they are located. As long as the new site for the TMT or redeveloped existing sites are configured similarly, no additional surface runoff would be created.

In contrast to the lack of runoff from the observatory sites, the access road from the Saddle Road up to and around the summit does create surface runoff and, to a limited extent, does alter the path of natural surface runoff from the mountain's slopes. Roadway lengths are from Saddle Road to Hale Pōhaku (all paved 10.1-km (6.3 mi)); from Hale Pōhaku to the summit (13.4-km (8.3 mi) of which 7.4 km (4.6 mi) is unpaved); and the loop around the summit, a portion of which is unpaved (2.7 km (1.7 mi). At an average width of 14 m (45 ft), including cuts and fills beyond the travel way and road shoulders, the total area of this 26.2 km (16.3 mi) of road is almost 36 ha (90 ac). This area is relatively small in relation to the mountain itself. For example, it is less than one percent of the 4,452-ha (11,000-ac) MKSR that is entirely above 3,658-m (12,000-ft) elevation.

Depending on road slopes, drainage improvements, and adjacent topography, surface runoff from the roadway and shoulders sheet flows off the road prism or is conveyed in road swales to specific discharge points. Because there are numerous points of discharge along the road and the rates of discharge at each point are relatively modest, the identifiable effects, including minor erosion and deposition of silt, sand, and gravel, are limited to tens to several hundred feet downslope from the points of discharge. Another significant aspect is that none of the identifiable paths of surface runoff extend to or below 1,829-m (6,000-ft) elevation. In other words, most of the surface runoff ultimately becomes groundwater recharge, with a small amount lost to evaporation. From this perspective, the fact that there is surface runoff from the roadways does not alter the ultimate fate of the originating precipitation.

Assuming that the 7.4-km (4.6-mi) long unpaved road segment above Hale Pōhaku is ultimately paved, the amount of surface runoff would increase slightly, but the volume of sediment carried off the road surface and downslope would be substantially reduced. On balance, this would be an improvement over existing conditions.

Subsurface Disposal of Domestic Wastewater. Subsurface disposal of wastewater occurs in two general locations: (1) the seven cesspools and two septic systems at Hale Pōhaku, and (2) individual observatory sites at the summit. Each observatory on Mauna Kea operates an individual wastewater system (IWS) approved by the State of Hawaiʻi Department of Health (UH 1999). No plan exists to replace these systems with a common sewage system (UH 1999). Licensed septic waste haulers pump the digested biosolids from each IWS periodically. The IWSs are inspected by observatory maintenance crews periodically. The exceptions are VLBA, UKIRT, and JCMT which do not inspect or pump out their systems periodically (JAC 2004b; VLBA 2004).

The only wastewater entering these systems is from domestic sources (e.g., sinks, toilets, urinals) and cleaning water (e.g., mop water). Prior to 2002, CFHT and the W.M. Keck Observatory directed process wastewater from mirror decoating into their respective IWSs. Due to concerns from community groups, this practice has been discontinued.

Hale Pōhaku. Based on the assumptions presented at the start of this section, the current 14 klpd (3,800 gpd) of wastewater disposal at Hale Pōhaku could ultimately increase to 18 klpd (4,730 gpd). At the summit, the current 7 klpd (1,780 gpd) of wastewater disposal could increase to 8.4 klpd (2,215 gpd). Both are increases approximately 25 percent higher than the current rates of discharge.

A conservative analysis of the impact of subsurface wastewater disposal at Hale Pōhaku was presented in Section 4.1.3.2. That analysis was based on the period of construction of the Outrigger Telescopes when wastewater generation at Hale Pōhaku was estimated to vary between 20 and 25 klpd (5,300 and 6,500 gpd) over a 24-month period. The subsurface wastewater discharge rates assumed for that analysis would be somewhat less than the anticipated, long-term 18-klpd (4,730-gpd) rate of disposal at Hale Pōhaku, making the previous results equal to or greater than the long-term impacts. Key findings of that analysis are summarized as follows:

- Because of Hale Pōhaku's location relative to Mauna Kea's south rift zone, wastewater percolating through the vadose zone would be likely to move in an easterly direction toward the Hilo area.
- If all removal and/or degradation of nutrients in the wastewater are ignored, including that which occurs in the cesspool and septic tank systems, through the thousands of feet of movement through the vadose zone, and during the tens of miles of travel in groundwater, only dilution would be available to mitigate the impact of the discharges. The rate of dilution would be at least 12,000 to 25,000 times. As a result of dilution alone, nutrient concentration levels in wells to the east of the summit would be essentially negligible compared to the natural

levels in pristine Hawaiian groundwater.

- Because nutrient removal and degradation would actually occur over this decades-long travel route, no actually measurable impact would occur.

There will be a period of time during the construction of TMT when up to 60 construction workers may be temporarily housed at the Hale Pōhaku. During this period, water use and wastewater disposal at the Hale Pōhaku may temporarily be on the order of 38 klpd (10,000gpd). This is greater than the rates used for the period of construction of the Outrigger Telescopes (up to 25 klpd (6,500 gpd)) and the anticipated longer-term rates after the TMT is completed (18 klpd (4,730 gpd)). However, the same assumptions used for the analysis in Section 4.1.4.2 are still applicable and the conclusions reached are still the same. By dilution alone, impact of the temporary increase of wastewater produced by TMT construction workers residing at Hale Pōhaku would be negligible. Actual degradation of organic matter in the wastewater will occur over the decades-long travel path, further mitigating this temporary impact.

Observatory Sites. In Section 4.1.3.2, the impact of the subsurface disposal of 1.8 klpd (480 gpd) of domestic wastewater from the W.M. Keck Observatory septic system is analyzed. Key points of that analysis, which are relevant to an analysis of cumulative impacts of subsurface wastewater discharges at the summit, would be:

- For the reasons given previously, none of the subsurface disposal of wastewater at the summit observatories would end up in Lake Waiau or as discharge from any of the perched springs on the west side of Pōhakuloa Gulch.
- Based on the locations of the observatories relative to the mountain's rift zones and a conservative estimate of impact, it is assumed that percolating wastewater at the summit would move to the south and/or west.
- The nearest wells in that general direction are 20.2-km (12.6-mi) away in Waiki'i.

Based on the series of assumptions provided in Section 4.1.3.2, increases in the Waiki'i wells of nitrogen and phosphorus percentages of 2 klpd (480 gpd) of wastewater discharged at W.M. Keck Observatory were calculated to be 0.4 and 1.6 percent, respectively.

If this same series of assumptions as described in Section 4.1.3.2 are used, the anticipated long-term total wastewater discharge at the summit of 8.4 klpd (2,215 gpd) could result in nitrogen and phosphorus increases in the Waiki'i wells of no more than 1.8 and 7.4 percent, respectively. Increases of this magnitude would not impair use of the Waiki'i wells for potable water consumption.

The actual increases would likely be far less than estimates using a series of conservative assumptions. Nutrient removal rates in the decades-long travel time from the summit to the Waiki'i wells would be far greater than assumed and capture of all the remaining nutrients by the Waiki'i wells, also one of the assumptions of the analysis, would be a highly improbable result.

4.2.5.3 Cumulative Impact Summary

The impact of all past, present, and reasonably foreseeable future astronomy related projects, including the Outrigger Telescopes Project, on the hydrologic system is negligible. Therefore, the cumulative impact on hydrology and water quality is not significant.

4.2.6 Solid Waste and Hazardous Materials Management

4.2.6.1 ROI for Solid Waste and Hazardous Materials Management

The ROI for solid waste and hazardous materials depends on the material and the manner of release. For example, wind-blown trash could be transported anywhere across the mountain, while a spill on cinder and clean-up of several liters of liquid would most likely be confined to the immediate area. For purposes of this evaluation, the ROI is the area within the MKSR, a corridor surrounding the Mauna Kea Access Road and the Saddle Road, and the potential surface and subsurface water flow paths.

4.2.6.2 Impacts of Past and Present Activities on Solid Waste and Hazardous Materials Management

Solid Waste. Past construction activities on Mauna Kea have generated debris, and past facility operations have generated trash and other solid waste. These materials have been collected in containers, removed periodically from the site, and disposed of at authorized landfills. However, there have been releases of these wastes on Mauna Kea. As described in Section 4.2.4.3, researchers performing a botanical survey in 1982 reported a considerable amount of trash around the mountaintop. Trash can have a detrimental effect on flora and fauna and can spoil the visual appeal of the surroundings. UH responded to this concern in the 1999 MKSR Master Plan EIS by accepting responsibility for waste removal within the MKSR. Since then, trash has been collected by Mauna Kea Support Services, including trash left by visitors to the summit, and is now rarely seen within the MKSR.

Trash generation rates for present facility operations are given in Table 4-16. Estimates range from one 110-l (30-gal) bag weekly at the VLBA and JAC to 1.1 kl (290 gal) daily at Hale Pōhaku. The aggregate weekly rate is approximately 16.7 kl (4,400 gal). Each facility puts its trash in standard containers for transport and disposal off site.

The impacts to flora, fauna, and aesthetics as a result of past and present solid waste generation have been small, transient, and not significant.

Hazardous Materials. Past construction activities and facility operations on Mauna Kea required the use of and generated waste from hazardous materials, including paints and solvents, vehicle and generator fuel, lubricants, hydraulic fluid, glycol coolants, acids (used in mirror decoating), and mercury. Despite best efforts to prevent spills, a small number have occurred since observatory operations began at the summit. Hazardous material releases, if large, can potentially have an adverse effect on biological and water resources and can degrade aesthetics by discoloring the ground. Table 4-17 summarizes known spills that have occurred either at the summit, along the Mauna Kea Access Road, or at Hale Pōhaku. Some of these spills occurred within the confines of an observatory building and usually did not reach the outside environment. Others occurred outside and were, in most cases, identified immediately and cleaned up quickly and thoroughly, eliminating any potential for lasting impact. Best available information suggests none of the mercury spills reached the outside environment. However, the mercury spills prompted recommendations for better equipment and training at the Canada-France-Hawaii

TABLE 4-16. CURRENT WASTE AND HAZARDOUS MATERIALS USE AT THE MAUNA KEA OBSERVATORIES AND HALE PŌHAKU

Observatories	UH (0.6-m (24-in) and 2.2-m (88-in))	CFHT	NASA IRTF	UKIRT	CSO	JCMT	VLBA	W.M. Keck Observatory	Gemini North	Subaru Telescope	SMA	Hale Pōhaku Mid-Elevation Support Facilities
Start of Operations	1968 (0.6 m (24 in)) 1970 (2.2 m (88 in))	1979	1979	1979	1987	1987	1992	1992 Keck I 1996 Keck II	1999	1999	2002	1980s
Safety and/or Hazardous Materials Management Plan	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available	Written plan available
Hazardous Material Disposal and Recycling	Licensed hazardous waste transporters transport any hazardous waste to a licensed disposal facility	Contractor handles hazardous material, offsite disposal; waste streams include ethylene glycol, hydraulic fluid, diesel fluid, refrigerant, oils and lubricant, paint and related solvents	Licensed hazardous waste transporters transport any hazardous waste to a licensed disposal facility	Contractor handles hazardous material, offsite disposal	Contractor handles hazardous material, offsite disposal	Contractor handles hazardous material, offsite disposal	Used gear box oil shipped to HQ in New Mexico and disposed by contractor	Contractor handles hazardous material, offsite disposal	AC system and used generator oil, ethylene glycol, paint, solvent, oily rags, all trucked to Hilo and disposed by Unitek; refrigerant is recycled	Contractor handles hazardous material, offsite disposal	Hydraulic oil from antenna transporter disposed of by oil processor in Hilo	Licensed hazardous waste transporters transport any hazardous waste to a licensed disposal facility

TABLE 4-16. CURRENT WASTE AND HAZARDOUS MATERIALS USE AT THE MAUNA KEA OBSERVATORIES AND HALE PŌHAKU (CONTINUED)

Observatories	UH (0.6-m (24-in) and 2.2-m (88-in))	CFHT	NASA IRTF	UKIRT	CSO	JCMT	VLBA	W.M. Keck Observatory	Gemini North	Subaru Telescope	SMA	Hale Pōhaku Mid-Elevation Support Facilities
Mirror De-coating and Re-aluminizing	Performed at the UH 2.2-m (88-in) observatory, 113 l (30 gal) of liquid waste from stripping (HCl, $CuSO_4$, $CaCO_3$, Alconox); Since 2000, effluent containerized for offsite disposal; aluminum applied by vapor deposition; recoating every two years	Performed in summit observatory; 2,300 l (600 gal) water, HCl, $CuSO_4$, neutralized w/ slurry of $CaCO_3$; Since May 20002, effluent containerized for offsite disposal; aluminum re-coating applied by vapor deposition, one mirror processed per year	Performed at CFHT, mirror processed every 3 to 4 years	Performed at CFHT	N/A	N/A	N/A	Performed in summit observatory; 150 l (40 gal) water, HCl, $CuSO_4$, neutralized with slurry of KOH; Since 2002, effluent containerized for offsite disposal; aluminum re-coating applied by vapor deposition, up to four mirrors processed per month	Performed in summit observatory; HCl solution, KOH and $CuSO_4$, neutralized with a slurry of $CaCO_3$ and KOH, 90 l (25 gal) of solution, up to 4,200 l (1,100 gal) rinse water; effluent containerized for offsite disposal; aluminum re-coating applied by sputtering plasma flow with no waste; coated primary in Jan 2004, previous April 2000	Performed in summit observatory; HCl, $CuSO_4$, ethanol, neutralized w/ baking soda and up to 10,000 l (2,600 gal) water, baking soda; effluent containerized for offsite disposal	N/A	N/A
Fuel for Back-up Generator	Propane, two 40-l (10.6-gal) tanks attached to generator; generator used once in 10 years	Diesel, 7,600 l (2,000 gal) in 19,000-l (5,000-gal) underground storage tank, 280 l (75 gal) in generator; fuel oil is replaced as needed every few years	No back-up generator	Diesel, one 19-l (5-gal) fuel container stored outside; estimate 1/4 container used yearly	Propane, four 45-kg (100-lb) storage tanks refilled at 3 to 5 year intervals	Propane, eight 87-l (23-gal) tanks stored outside; estimate 1/4 tank used yearly	Diesel, 950-l (250-gal) double walled tank; replenishe d about once yearly, rarely used	Diesel, 9,500-l (2,500-gal) double walled underground storage tank	Diesel, 680-l (180-gal) double walled tank underneath generator; exercise the generator one hour weekly, then tank topped off with 30 l (8 gal) fuel	Diesel, 3,800-l (1,000-gal) underground tank; refilled every few years	Diesel, 3,800-l (1,000-gal) double walled above ground tank; generator not yet installed	No back-up generator

TABLE 4-16. CURRENT WASTE AND HAZARDOUS MATERIALS USE AT THE MAUNA KEA OBSERVATORIES AND HALE PŌHAKU (CONTINUED)

Observatories	UH (0.6-m (24-in) and 2.2-m (88-in))	CFHT	NASA IRTF	UKIRT	CSO	JCMT	VLBA	W.M. Keck Observatory	Gemini North	Subaru Telescope	SMA	Hale Pōhaku Mid-Elevation Support Facilities
Hydraulic Fluid	1,500 l (400 gal) in use, 570 l (150 gal) in storage, replaced every 5 years	1,135 l (300 gal) in use, 2,100 l (600 gal) in storage; systems replenished once in past 10 years	340 l (90 gal) in use, 19 l (5 gal) in storage, replaced as needed	Less than 114 l (30 gal) in use in both UKIRT and JCMT; less than 19 l (5 gal) in storage	190 l (50 gal) in use, 19 l (5 gal) in storage, added to equipment as needed	Less than 114 l (30 gal) in use in both UKIRT and JCMT; less than 19 l (5 gal) in storage	106 l (28 gal) in use, 76 l (20 gal) in storage, replaced yearly	4,500 l (1,200 gal) in use, 208 l (55 gal) in storage	1,500 l (400 gal) in use, replaced as needed every several years	2,600 l (690 gal) reservoir, 208 l (55 gal) in storage	380 l (100 gal) in use, 150 l (40 gal) in storage	Normally less than 208 l (55 gal) on hand, recycle 760 l (200 gal) yearly
Cooling Media	Liquid nitrogen, use 300-l (80-gal) monthly; R-22 in use, two 14-kg (31-lb) containers in storage; ethylene glycol, 380 l (100 gal) in use, 190 l (50 gal) in storage	50:50 mixture glycol + water 1,900 l (500 gal) in use, 830 l (220 gal) in storage; liquid nitrogen used 640 l (170 gal) monthly (evap), 320 l (85 gal) stored; helium also used, one cylinder in storage; refrigerants used, 73 kg (160 lb) R-502 and 23 kg (50 lb) R-404a	Propylene glycol, 302 l (80 gal) used, replaced as needed; stores 38 l (10 gal) @100 percent, 320 l (85 gal) @ 40 percent w/ water; liquid nitrogen and liquid helium in use; refrigerants used, 91 kg (200 lb) R-134A and 68 kg (150 lb) R-409A	Ethylene glycol + water mixture, 227 l (60 gal) in use	50:50 Mixture ethylene glycol and water 76 l (20 gal); 100 l (26 gal) helium, 120 l (32 gal) nitrogen, equal amounts stored; use rates, 100 l (26 gal) helium weekly, 120 l (32 gal) nitrogen monthly	Ethylene glycol + water mixture, 170 l (45 gal) in use	Helium, one 8,300-l (2,200-gal) bottle used every three years, one bottle in storage; Refrigerant R-22, 5.9 kg (13 lb) in use, 1 kg (2.2 lb) in storage	Propylene glycol, 1,135 l (300 gal) in use, ethylene glycol, 1,135 l (300 gal) in use; 2,270 l (600 gal) glycols in storage	60/40 mixture ethylene glycol/water, 4,162 l (1,100 gal) in use, 416 l (110 gal) in storage; closed cycle helium cooling for instruments, none consumed, a few helium gas cylinders stored	Ethylene glycol, 13.6 kl (3,600 gal) in use, 416 l (110 gal) in storage, refilled as necessary; refrigerant R-22, 227 kg (500 lb) in use, none stored	Glycol + water mixture, 189 l (50 gal) in use, 114 l (30 gal) in storage; refrigerant R-22, 82 kg (180 lb) in use, none stored	None used at facility
Paint, Related Solvents	About 38 l (10 gal) on site, mostly spray cans, several used per month as needed	38 l (10 gal) paint on site, used for occasional touch up	189 l (50 gal) on site, used on monthly basis depending on job requirements	Less than 19 l (5 gal) onsite	Paint, 83 l (22 gal) on site for cosmetic touch up; thinner, 7.6 l (2 gal) on site	Less than 19-l (5-gal) onsite	Acrylic roof coating 19 l (5 gal), spot repairs, once per year	Various amounts on site, used as needed	About 76 l (20 gal) in storage; thinner, several liters in storage; used maybe once per week	None on site	Paint and primer 45 l (12 gal) in use and storage; mineral spirits 7.6 l (2 gal) in use and storage	Solvent, 190 l (50 gal) mostly in parts washer, recycled

TABLE 4-16. CURRENT WASTE AND HAZARDOUS MATERIALS USE AT THE MAUNA KEA OBSERVATORIES AND HALE PŌHAKU (CONTINUED)

Observatories	UH (0.6-m (24-in) and 2.2-m (88-in))	CFHT	NASA IRTF	UKIRT	CSO	JCMT	VLBA	W.M. Keck Observatory	Gemini North	Subaru Telescope	SMA	Hale Pōhaku Mid-Elevation Support Facilities
Oil and Lubricant	Lube, 76 to 114 l (20 to 30 gal) in use	Oil and lube, 95 l (25 gal) in storage	114 l (30 gal) stored on site	Between UKIRT and JCMT, about 76 l (20 gal) stored on site	Grease, about 23 kg (50 lb), and lubricants, 45 l (12 gal) stored onsite	Between UKIRT and JCMT, about 76 l (20 gal) stored on site	Gear lube, 19 l (5 gal), grease, 57 l (15 gal), and motor oil, 7.6 l (2 gal) in storage	Oil, 3,800 l (1,000 gal) in use, 380 l (100 gal) in storage	Grease, about 23 kg (50 lb), and oils, 380 l (100 gal) in storage	Lubricant for periodic service of back up generator, none stored onsite	Engine oil, 34 l (9 gal) in use, 38 l (10 gal) in storage; lubricant 4.5 kg () 10 lb) in use, 4.5 kg (10 lb) in storage	Oil, less than 380 l (100 gal) in storage
Mercury	Primary mirror support for 2.2-m (7.2-ft) only, 13.6 kg (30 lb) in use, 9.1 kg (20 lb) in storage	Mercury used in radial support tube for secondary mirror; 7.7 kg (17 lb) in use, 9.5 kg (21 lb) in reserve	About 51 kg (112 lb) in support tube for primary mirror, none held in reserve	No mercury used	No mercury used	No mercury used	No mercury used	1.4-m (4.6-ft) secondary mirror support; 5.9 kg (13 lb) in use, 7.7 kg (17 lb) in storage	No mercury used other than a few thermometers	No mercury used	No mercury used	No mercury used
Trash	Two to three 114-l (30-gal) bags weekly	Four bins, 1.5 m^3 (2 yd^3) each, generated monthly	Three 114-l (30-gal) trash bags weekly	About one 114-l (30-gal) trash bag for both facilities weekly (UKIRT and JCMT)	About 900 kg (2,000 lb) generated yearly	About one 114-l (30-gal) trash bag for both facilities weekly (UKIRT and JCMT)	One 114-l (30-gal) bag weekly	2.3 m^3 (3 yd^3) dumpster emptied 1 to 2 times weekly	Several 190-l (50-gal) trash bags weekly	18 kg (40 lb) generated daily	Two to four 190-l (50-gal) drums weekly	0.7 to 1.1 m^3 (0.9 to 1.5 yd^3) daily
Green Products	Try to use environmentally friendly products whenever possible	Mindful of selecting green products	Seek better products on an as needed basis, switch to friendly products whenever possible	No information	Does not survey market-place for such products	No information	Routinely survey the market-place for these items	Surveys periodically for green products	Surveys marketplace for green products	Does not survey marketplace for such products	Surveys periodically for green products	Not routinely, but does have an upgraded parts washing facility

Notes:
N/A means category not applicable

TABLE 4-17. HAZARDOUS MATERIAL AND SEWAGE SPILLS ASSOCIATED WITH ASTRONOMY OPERATIONS ON MAUNA KEA

Date	Location	Material(s)	Accident/Response
1979 (estimated)	CFHT Facility (indoors)	Hydraulic fluid	A hydraulic system filter clogged, leading to the backfilling of a drain, which overflowed and caused roughly 1.9 l (0.5 gal) of hydraulic fluid to spill onto an optical tube. There is also anecdotal recollection of a spill and cleanup related to a burst hydraulic pump in the early years of observatory operation.
1982	Now known as the summit area construction staging area	Diesel fuel	During a biological survey, Howarth and Stone (1982) noted an area of staining (18 m^2 (194 ft^2)) on the ground near a temporary generator and suspected a diesel fuel spill. The generator has since been removed.
1989	NASA IRTF (indoors)	Mercury	A mercury spill (9 kg (20 lb)) resulted from the puncture of the primary mirror support ring. Cleanup was performed in accordance with written observatory procedures using commercial products designed for mercury recovery.
October 3, 1990	CFHT Facility (indoors)	Mercury	Mercury spill from a pinched secondary mirror support bladder. Facility was evacuated temporarily during cleanup.
1995	W.M. Keck Observatory (indoors)	Mercury	Three mercury spills have occurred at the observatory: August 10, 1995, while working on f/15 secondary, resulting in a 5-ml (1- teaspoon) spill. September 15, 1995, while working on f/15 secondary mirror, resulting in a 100-ml (7-tablespoon) spill. November 6, 1995, while transferring mercury between containers, resulting in a spill of 5 to 10 ml (1 to 2 teaspoons). All three spills occurred in the mirror handling room, and were cleaned up promptly. None resulted in any mercury seepage into the ground or the septic system. As a result of these incidents, the observatory revised mercury handling and response procedures. No subsequent mercury spills have occurred.
November 3, 1995	Mauna Kea Access Road near Very Long Baseline Array	Diesel fuel, engine and hydraulic oil	Truck involved in construction of SMA overturned, causing fuel tank and engine lines to rupture, releasing approximately 227 l (60 gal) of fluids onto surface cinder; impacted media were excavated and removed by truck owner within 24 hours.
September 3, 1996	Subaru Telescope	Ethylene glycol	Release occurred when a pallet carrying two 208-l (55-gal) containers failed, and the containers fell to the cinder and ruptured. Cleanup was performed immediately to recover free liquid and excavate affected cinder. All contaminated materials were bagged and disposed of.

TABLE 4-17. HAZARDOUS MATERIAL AND SEWAGE SPILLS ASSOCIATED WITH ASTRONOMY OPERATIONS ON MAUNA KEA (CONTINUED)

Date	Location	Material(s)	Accident/Response
1998 (estimated)	UH 2.2-m Telescope facility (indoors)	Mercury	More than 5 years ago a few drops of mercury escaped on several occasions while the mirror support ring was being drained or refilled during the recoating process. These were cleaned up according to the UH mercury cleanup procedures.
January 15, 1998	Subaru Telescope	Sewage	Improper installation of septic tank led to freezing, which created a clog and a spill of about 7.6 l (2 gal) on the ground and snow. A plumber repaired the clog, and the observatory added cinder atop the septic system to insulate against freezing.
June 5, 1998	CFHT facility (indoors)	Mercury	In order to align a lens, a pool of mercury was lifted to the bottom of the lens to create a reflected image. During the procedure about a "thimble full" of mercury spilled from an overflow dish to the concrete floor. The mercury was cleaned up quickly. Afterward, recommendations were made for additional training and better equipment for containment.
1990 to 2000 (date estimated)	Caltech Submillimeter Observatory	Hydraulic fluid	In past years, on a few occasions, small amounts of hydraulic fluid seeped out of joints in the dome hydraulic system and dripped onto the concrete pad under the dome. No fluid traveled beyond the concrete pad. An ongoing hydraulic system inspection program detects any seepage source. The source is eliminated, and all traces of fluid on the concrete pad are immediately cleaned up.
2003 (date estimated)	Hale Pōhaku	Crankcase oil and hydraulic fluid	Crankcase oil and hydraulic fluid leaked from a piece of equipment. The soil was excavated, tested, and sent to a landfill in compliance with State health department regulations. The facility has taken measures to reduce the likelihood of this type of spill recurring.
2003	Hale Pōhaku	Transmission oil	Two oil drips beneath an old truck used to transport mirror for the Joint Astronomy Center. Total amount of the leakage estimated at less than 950 ml (1 qt). The Joint Astronomy Center dug out cinders under drip areas and removed them for disposal. Absorbent pads were used to stop further drips; the truck was removed.
2003	Smithsonian Astrophysical Observatory Submillimeter Array	Hydraulic fluid	Hydraulic leak onto asphalt, about 473 ml (0.5 qt), caused by decayed seals. Cleaned using approved "pig-mat" absorbent material, which was disposed of appropriately.
February 2004	Smithsonian Astrophysical Observatory Submillimeter Array	Diesel fuel	Diesel leak onto asphalt, less than 3,800 ml (4 qt), caused by decayed seals. Cleaned using approved "pig-mat" absorbent material, which was disposed of appropriately.

TABLE 4-17. HAZARDOUS MATERIAL AND SEWAGE SPILLS ASSOCIATED WITH ASTRONOMY OPERATIONS ON MAUNA KEA (CONTINUED)

Date	Location	Material(s)	Accident/Response
March 30, 2004	W.M. Keck Observatory	Propylene glycol	The spill occurred during testing of an auxiliary glycol cooler when one of the hoses accidentally became dislodged from its barbed fittings. Spill estimated between 76 and 114 l (20 and 30 gal), with approximately two-thirds escaping outside the facility. The CARA Safety Officer handled spill response; affected cinder was contained, removed, and disposed of at a local landfill. The observatory notified OMKM, which advised on disposal.

facility and a revision to mercury handling and response procedures at the W.M. Keck Observatory.

Current facility operations on Mauna Kea use and generate waste from similar types of hazardous materials. Table 4-16 summarizes current hazardous materials use and applications at the observatories and Hale Pōhaku. The facilities use many of the same hazardous materials, with some notable exceptions. Of the eight optical observatories, only five perform mirror recoating operations on site (UH–2.2 m, CFHT, W.M. Keck, Gemini North, and Subaru) and only four use mercury for mirror support (UH–2.2 m, CFHT, IRTF, and W.M. Keck).

Each facility has written procedures for handling hazardous materials and provides training for workers involved in such activity. In addition, each observatory has emergency procedures for responding to chemical spills.

In summary the impacts to biological resources and aesthetics as a result of past and present handling of hazardous materials (i.e., accidental spills) have been small and not significant.

4.2.6.3 Impacts of Reasonably Foreseeable Activities on Waste and Hazard Materials Management

Solid Waste. Reasonably foreseeable future activities, whether new construction, facility redevelopment, or continued operation of current facilities, would presumably generate solid wastes similar to those described under past and present activities.

For the purposes of this analysis, it is assumed that, during construction, mitigation measures would be implemented to reduce the possibility of waste dispersal, e.g., securing lids and/or heavy tarps over disposal containers and construction materials; securing outdoor receptacles to the ground; and arranging for more frequent waste removal.

Solid waste streams related to facility operations would increase if proposed new facilities, such as the TMT, are constructed. It is assumed these waste streams would be handled in a fashion similar to other observatories. It has been assumed for the purpose of this evaluation that the TMT would generate trash at a rate similar to that of the W.M. Keck Observatory (i.e., 4.6 m^3 (6 ft^3) per week). Facility redevelopment, if realized, would likely increase the amount of solid waste generated, but only slightly in proportion to additional staff. As observatories become more remotely operated, the amount of waste generated at the Mauna Kea summit would be reduced.

There are no future plans to consolidate waste containerization among observatories on the summit.

It is assumed that proposed development of non-astronomy-related facilities (e.g., the remotely operated microwave facility) and communities (e.g., DHHL land development) would have similar waste management practices.

Overall, no significant impact from solid waste management within the ROI is expected from reasonably foreseeable future activities.

Hazardous Materials. It is assumed that reasonably foreseeable future activities would use and generate waste from hazardous materials similar to those generated by past and present activities.

It has been assumed for the purpose of this evaluation that the TMT would use and generate waste from hazardous materials at a rate similar to that of the W.M. Keck Observatory.

It is assumed that new or redeveloped facilities would each have written standard operating and emergency procedures for handling hazardous materials and would provide training for workers accordingly.

It is assumed that contractors would provide only the necessary amounts of paints and solvents on the summit, eliminating temporary storage needs there, and that transportation of hazardous materials and waste would be coordinated with other construction traffic to minimize the chance for an accident and release at the summit or along the Mauna Kea Access Road.

Given these assumptions and other procedures available to manage hazardous materials, no significant impacts within the ROI are expected from reasonably foreseeable future activities.

4.2.6.4 Cumulative Impact Summary

Solid Waste. Impacts of solid waste on biological or hydrological resources or aesthetics from past, present, and reasonably foreseeable activities have been small, if any, transient, and not significant. Table 4-18 compares the estimated solid waste load of the Outrigger Telescopes Project to past, present, and reasonably foreseeable generation rates for the summit observatories and Hale Pōhaku. The data show a minor increase due to the Outrigger Telescopes Project. The incremental impact of the Outrigger Telescopes Project would therefore be small and not significant.

Hazardous Materials. Impacts of hazardous materials on biological resources or aesthetics from past, present, and reasonably foreseeable activities have been small and not significant. Table 4-16 compares the estimated hazardous materials use of the Outrigger Telescopes against past, present, and reasonably foreseeable use rates for the summit observatories and Hale Pōhaku. The data show minor increases resulting from the Outrigger Telescopes and no mercury or glycol use. The incremental impact of the Outrigger Telescopes Project would therefore be small and not significant.

4.2.7 Geology, Soils, and Slope Stability

4.2.7.1 ROI for Geology, Soils, and Slope Stability

For this discussion, geology, soils, and slope stability refers to the impact of human activity on all geologic features of Mauna Kea, especially on the morphology of cinder cones and on the processes of erosion, which can cause the excavation, transport, and redeposition of soils and cinders.

The ROI for assessing the potential impacts from implementing the Outrigger Telescopes Project on geology, soils, and slope stability would be the summit of Mauna Kea, Hale Pōhaku, construction staging and laydown locations, and on roadways that connect these facilities.

4.2.7.2 Impacts of Past and Present Activities on Geology, Soils, and Slope Stability

The development of each Mauna Kea summit observatory has been accompanied by localized site developments that have significantly modified the preexisting landscape and impacted geologic structures and slope stability. The development of the NASA IRTF, the W.M. Keck Observatory, and the Subaru Telescope were accompanied by great modification of the physiography of Pu‘u Hau‘oki and the unnamed cinder cones to the west, as connecting roads were built (Figure 4-2) and as the tops of these cones were flattened to prepare foundations for the telescopes. Most of the material removed from these

TABLE 4-18. EFFECT OF THE OUTRIGGER TELESCOPES ON SOLID WASTE GENERATION AND HAZARDOUS MATERIALS USE ON PAST, PRESENT, AND REASONABLY FORESEEABLE FUTURE ACTIVITIES AT THE MAUNA KEA OBSERVATORIES AND HALE PŌHAKU

Material Class	Total of Past, Present, and Reasonably Foreseeable Future Activities at Mauna Kea Observatories and Hale Pōhaku	Anticipated Increment of Outrigger Telescopes Project
Glycol cooling media	More than 24,000 l (6,300 gal) total in use and storage	No glycol used
Fuel storage for backup generator	Diesel, 26,600 l (7,000 gal) Propane, more than 1,000 l (264 gal)	No fuel required; emergency power provided by existing infrastructure
Hydraulic fluid	About 16,000 l (4,200 gal) total in use and storage	No hydraulic fluid used
Oil and lubricants	About 5,700 l (1,500 gal) total in use and storage	Gear oil (66 l (17 gal) per Outrigger Telescope) and grease used; no additional lubricants stored on site
Mercury	About 82 kg (180 lb) total in use and storage	No mercury used
Mirror decoating, recoating	More than 52 mirrors decoated and recoated each year	Up to three mirrors decoated and recoated each year.
Paints and related solvents	Total in use and storage: Paint, more than 525 l (140 gal) Solvent, more than 200 l (53 gal)	Used as needed; no additional paint and solvents stored on site
Trash	About 16.3 m^3 (21.3 ft^3) generated weekly	About 0.6 m^3 (0.8 ft^3) generated weekly

cones was transported away for use elsewhere or deposited on the floor of the Pu‘u Hau‘oki crater, but some material was pushed over the sides of the cones. These small areas of disturbed, redeposited rock and soil debris have steeper slopes than the preexisting natural slopes, which had become gentler and more stable over the past tens of thousands of years since their formation through natural processes (Hooper 1998). The artificially steepened slopes consist of poorly consolidated loose cinders, lava fragments, and admixed sand that are more easily disturbed than the materials of original, preconstruction slopes.

The construction of the access road to Mauna Kea’s summit caused localized modification of preexisting terrain, through excavation of road cuts and filling of natural low-lying areas. Subsequent to construction, significant erosion of loosened materials adjacent to the unpaved sections of the access road has occurred during times of heavy rainfall or rapid snow erosion, and this erosion has transported large quantities of sand and gravel to low-lying areas as much as 91 m (300 ft) downslope from the road, especially onto the flat-lying area northeast of Pu‘u Keonehehee (Figure 4-3). This erosion and redeposition occurred some time after December 1976, since aerial photos taken at that time do not show these deposits. Major efforts to mitigate this problem have been successful through the construction of settling basins along the roadway which trap sediment and allow road runoff water to percolate into the highly

FIGURE 4-2. ROAD ALONG THE WEST SLOPE OF PU‘U HAU‘OKI

Note the steepened angles of the artificial slope versus the natural undisturbed slope below.

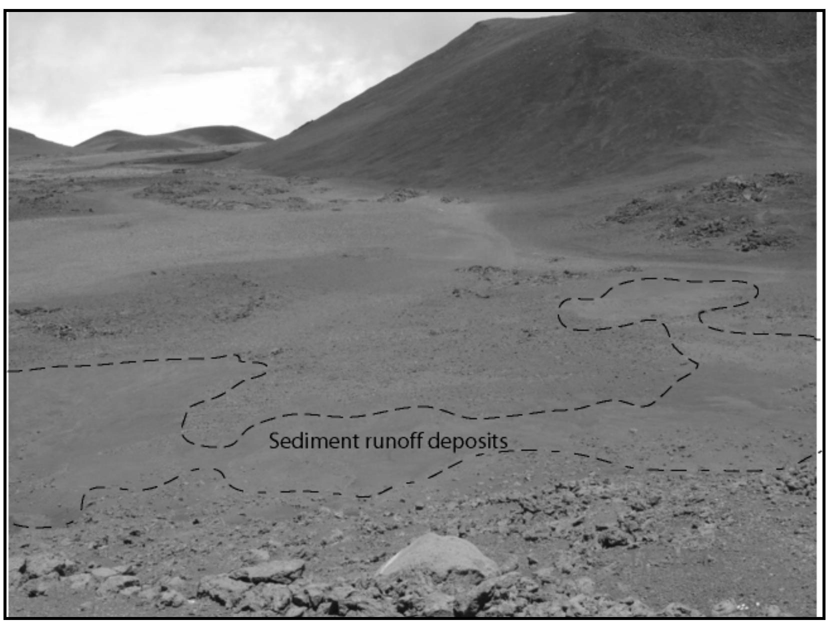


FIGURE 4-3. RECENT SEDIMENT DEPOSITS BELOW MAUNA KEA ACCESS ROAD AT 3,505-M (11,500-FT) ELEVATION

Note these sediments were deposited by runoff from the roadway after construction.

permeable underlying rocks. Ongoing road grading operations result in debris being pushed over embankments in some places (Figure 4-4), but this material does not travel far onto undisturbed ground.

In summary the impact of past and present activities on geology, soils, slope stability has been substantial.

4.2.7.3 Impacts of Reasonably Foreseeable Future Activities on Geology, Soils, and Slope Stability

Reasonably foreseeable future activities, e.g., redevelopment of current summit ridge observatories, would not be expected to substantially alter the current topography of the summit cinder cones. These activities would potentially have a small impact on the geology, soils, and slope stability of very localized areas. It is assumed that, if the TMT were to be implemented on the northwest plateau, excavated cinders would not be used in a way that would impact other previously undisturbed surfaces. It is also assumed that adequate engineering standards would be maintained to prevent unwarranted settling or deformation of foundations during future seismic activity.

The impact of human foot travel over the summit cones also needs to be considered as a factor in the degradation of cone slopes as recreational visitor numbers increase. Human foot traffic can accelerate modification of cone slopes and disturb natural habitats. These impacts can be reduced by educating visitors to the fragility of the cinder cones and encouraging them to remain on roadways and established trails.

4.2.7.4 Cumulative Impact Summary

The impact of past and present activities on geology, soils, and slope stability has been substantial. The impact of foreseeable future activities is anticipated to be small. The Outrigger telescopes would add a small and not significant incremental impact. The overall cumulative impact has been significant.

4.2.8 Land Use and Existing Activities

4.2.8.1 ROI for Land Use and Existing Activities

The ROI for assessing land use impacts includes the MKSR, Hale Pōhaku, and a corridor surrounding the Mauna Kea Access Road and the Saddle Road. The ROI for assessing existing activities impacts includes these areas and the Mauna Kea Natural Area Reserve.

4.2.8.2 Impacts of Past and Present Activities

Although the formation of the Astronomy Precinct, Hale Pōhaku, and the roadways accessing these areas has been consistent with State land use policies, existing activities have been substantially affected by past and present actions. Observatory development and improved access to the summit have changed the conditions in which current activities, such as traditional cultural practices and hiking, occur. These impacts are evaluated in detail in relevant sections of this document. Overall, the past and present activities listed in Table 4-7 have resulted in a substantial impact on existing activities.

4.2.8.3 Impacts of Reasonably Foreseeable Future Activities

It is anticipated that most reasonably foreseeable future activities listed in Table 4-8 would be consistent with State and local plans and compatible with State land use designations. The reasonably foreseeable future activities compatible with current land use designations, i.e., astronomy-related activities consistent with the Conservation District and resource subzone

FIGURE 4-4. ROADWAY EMBANKMENT BELOW THE MAUNA KEA ACCESS ROAD AT 3,170-M (10,400-FT) ELEVATION

Note material from road-grading operations is pushed over the embankment, but does not travel far down slope.

designations, would result in little or no impact on land use. Reasonably foreseeable future activities that do not conform to the types of uses permitted by the State Land Use Commission would require the current land use designation to be amended for a new type of use. In particular, the DHHL Land Acquisition would require rezoning the land for residential or preservation, depending on the chosen use(s). This development could impact access to the MKSR or result in rerouting the access road because the land parcel overlays the existing roadway. Consequently, this action could result in substantial land use impacts.

With the exception of the DHHL Land Acquisition, it is anticipated that most reasonably foreseeable activities would not impact existing activities. The suitability of the land within the ROI for cultural and religious practices, astronomical and other scientific research, and a variety of recreational activities would remain similar to the present. Paving the remainder of the Mauna Kea Access Road could impact existing activities by providing improved access to the summit region.

In summary, foreseeably future activities would not impact land use and existing activities. Exceptions are the DHHL Land Acquisition and paving of the remainder of the Mauna Kea Access Road, which could potentially have substantial impacts.

4.2.8.4 Cumulative Impact Summary

Most past, present, and reasonably foreseeable future activities on Mauna Kea have been consistent with State and local plans and compatible with State land use designations. The Outrigger Telescopes Project would have no incremental impact on land use.

From a cumulative perspective, the impacts of past, present, and foreseeably future activities on existing activities on Mauna Kea are substantial. The addition of the

Outrigger Telescopes to the existing observatories on the mountain would have a small incremental impact.

4.2.9 Transportation

4.2.9.1 ROI for Transportation

Transportation refers to the movement of vehicles along roads. The ROI for assessing transportation impacts includes the MKSR and other areas affected by on-site construction, installation, and operations including Hale Pōhaku and vehicle travel routes.

4.2.9.2 Impacts of Past and Present Activities on Transportation

The road from the saddle to Mauna Kea has undergone significant realignments and improvements over the years. In the 1930s, a gravel road was established that enabled vehicles to travel to Hale Pōhaku. The first jeep trail to the summit was developed when the NASA-funded 30-cm (12-inch) telescope installation began in 1964. In 1975, the jeep trail to the summit was realigned to eliminate some of the steep grades and sharp turns in the original alignment. In 1985, with funding from the State of Hawaiʻi and the W.M. Keck Observatory, the Hawaiʻi DOT began to design a 6-m (20-ft) wide roadway beginning at Hale Pōhaku and looping around the summit. This trail was named after John Burns, the governor in office in the 1960s at the time of the initial observatory development on Mauna Kea. The roadway was later paved between the 3,597-m (11,800-ft) level and the summit.

The creation of access roads allowed visitors, including many Native Hawaiians, to travel to the summit area for the first time. Today, thousands of visitors and Native Hawaiians travel to Mauna Kea each year to participate in a variety of cultural, scientific, and recreational activities. Table 3-9 in Section 3.1.8.3 summarizes the current traffic volume within the ROI by showing the traffic associated with astronomy-related activities and traffic associated with other activities.

Generally, traffic levels are low; however, during construction periods or during major astronomical events, traffic can become congested. Such delays are infrequent and do not impede overall traffic circulation.

The increase in traffic volume associated with the past and present activities listed in Table 4-7 has also resulted in substantial changes to the natural setting of Mauna Kea, resulting in increased levels of noise, dust, air emissions, and visual impacts. See sections related to noise (Section 4.2.12), air quality (Section 4.2.13), and visual impacts (Section 4.2.14) for additional details. Overall, the past and present activities listed in Table 4-7 have had a substantial impact on transportation.

4.2.9.3 Impacts of Reasonably Foreseeable Future Activities on Transportation

Impacts from the reasonably foreseeable future activities listed in Table 4-8 would potentially generate similar transportation impacts as discussed in Section 4.1.12.2 for the Outrigger Telescopes Project. Traffic volume in the ROI would increase due to an increase in construction and operation activities associated with the reasonably foreseeable activities listed in Table 4-8. In addition, NASA expects the numbers of tourists to increase in the future.

Traffic volume associated with construction and installation activities of future projects would create a moderate short-term impact on the local traffic network, notably traffic delays. The overall number of service and support staff needed at the summit to operate potential facilities would create a small impact. In addition, the increase in remotely operated observatories could lessen the impact of traffic associated with facility operations.

Overall, traffic associated with the construction, installation, and operation of most facilities listed in Table 4-8 would remain relatively low and comparable to the Outrigger Telescope Projects traffic volumes discussed in Section 4.1.12.2. Construction efforts are expected to be larger for the TMT, resulting in a moderate traffic volume increase from current conditions. This increase is expected to have a moderate impact on the overall traffic conditions within the ROI.

Substantial impacts could result from projects that require roadway alterations and improvements, such as the Keanakolu and Saddle Road improvement projects. These projects would result in traffic delays in the short term and potential long-term impacts associated with alteration of the existing landscape. In addition, visitor traffic volume would eventually increase as a direct result of greater access to Mauna Kea.

Depending on the approved land use, additional transportation impacts would result from the DHHL Land Acquisition project. Its development could impede access to the MKSR or result in changes to the access road because the land parcel overlays the existing roadway. Increased development associated with the DHHL Land Acquisition would be expected to increase traffic along the Saddle Road. A residential community built along this corridor would generate community-based travel — residential, domestic, occupational, services, and education-related traffic — industrial, military, and recreational traffic. This would result in a substantial impact.

Transportation of minimal quantities of hazardous materials (e.g., diesel fuel, motor oil(s), paints, and solvents) and wastes would be expected throughout the course of constructing, installing, and operating additional facilities on Mauna Kea (see Section 4.2.7). Handling of these materials would be guided by best management practices. No impact is anticipated.

4.2.9.4 Cumulative Impact Summary

The past, present, and reasonably foreseeable future activities listed in Table 4-7 and 4-8 resulted in greater access for visitors and Native Hawaiians traveling to Mauna Kea. As a result, there has been a substantial increase in traffic volume along the access road. This increase has resulted in a substantial impact on the natural setting of Mauna Kea.

The on-site construction and installation of the Outrigger Telescopes would result in a small, short-term increase in the current traffic volume. Operations of the Outrigger Telescopes would contribute only a small increase in current traffic levels. From a cumulative perspective, the transportation impact on Mauna Kea has been significant. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have a small incremental impact.

4.2.10 Utilities and Services

4.2.10.1 ROI for Utilities and Services

The ROI for assessing cumulative impacts includes the Astronomy Precinct, the MKSR, Hale Pōhaku, and vehicle travel routes.

This section analyzes potential impacts on water supply, electrical supply and communications, and emergency services and fire suppression.

4.2.10.2 Impacts of Past and Present Activities on Utilities and Services

Water Supply. Each major facility at the summit and at Hale Pōhaku was designed with its own underground water storage and distribution system. Water is trucked weekly from Hilo to Mauna Kea. Table 4-19 provides the storage capacities of each observatory and of Hale Pōhaku. Currently, the observatories use approximately 208 kl (55,000 gal) of domestic water every month and the Mid-Elevation Support Facilities use 95 kl (25,000 gal). The past and present water supply to the ROI is insignificant compared to the overall demand for water on the island of Hawai'i.

Electrical Power and Communications. During the early years of telescope development, on-site generators provided power to individual facilities. This changed when construction of power lines began in 1985 (UH 1999). Once power lines were brought to Hale Pōhaku, additional construction efforts soon brought power to the summit via an underground distribution system. Initial construction of the distribution system was completed in 1988 (UH 1999). In 1995, an upgrade to the electrical system added an underground distribution loop at the summit and provided service to the SMA (UH 1999).

Power is currently provided to the summit by aboveground power lines that run from the Saddle Road to Hale Pōhaku and by the underground conduit between Hale Pōhaku and the underground distribution loop at the summit. The dynamics of the electrical distribution system for the summit are described in Section 3.1.9.2. Each observatory is connected to the underground distribution loop by a conduit line. The Hale Pōhaku substation has a capacity of 6,000 kVA, only about 53 percent of which is currently used. Each observatory manages its own power use and most have backup generators in case of a power outage. Table 4-19 provides the average annual electrical use for each observatory. Diesel fuel or propane is kept on site to fuel the generators as needed. Table 4-19 describes backup generator capacities and loads.

The initial communications system installation coincided with the power installation in 1985. Fiber optic cables were added in the 1990s via aboveground cables that attached utility lines to Hale Pōhaku, and from there by the existing electrical underground conduits, to the underground distribution loop at the summit that serves the observatories. These upgraded communication system capabilities, provided by Verizon, allow real-time communication between the summit facilities and on- and off-island headquarters offices, as well as Internet communication.

There have been no substantial impacts on the electrical or communication system other than the improvements listed above.

Emergency Services and Fire Suppression. Section 3.1.9.3 provides a general discussion of emergency preparedness procedures and programs that have been established for the Astronomy Precinct. MKSS has established a summit-wide Emergency Preparedness and Medical Evacuation Plan and encourages site-specific first aid and emergency training. Each observatory maintains a health and safety management plan that includes emergency planning procedures. Several facilities conduct additional training and drills with staff to ensure preparedness. Emergency plans contain fire prevention and safety procedures. Fire extinguishers and smoke alarms are located in all facilities. On January 16, 1996, three workers died in a fire during construction of the Subaru Telescope. The fire was caused during a

TABLE 4-19. OPERATIONS AND UTILITIES MANAGEMENT ON MAUNA KEA

Observatory	Type	Electrical Power Use[a] (Monthly) Backup Generators	Water Use (Monthly)[b] /Storage Capacity	Management Plans and Programs	Outreach and Education Programs
Subaru	O-IR	233,900 kWh/mo/ 270 kW backup generator with 3.8-kl (1,000-gal) diesel fuel tank	41 kl (10,958 gal)/ 38 kl (10,000 gal)	A[a], B	MKOOC[c], Base facility visitor's gallery
IRTF	IR	62,000 kWh/mo/ no backup generator	6 kl (1,688 gal)/ 15 kl (4,000 gal)	A[a], C[a]	MKOOC[c], IfA outreach
CFHT	O-IR	94,000 kWh/mo/ 250 kW backup generator with 19-kl (5,000-gal) diesel fuel tank	34-kl (8,975 gal)/ 2 x 23 kl (6,000 gal)	B, C[a]	MKOOC[c], Astronomy Education and Outreach Program
Gemini	O-IR	136,000 kWh/mo 118 kW backup generator with 681-l (180-gal) diesel fuel tank	15 kl (4,050 gal)/ 38 kl (10,000 gal)	A[a], B	MKOOC[c], Public Information and Outreach Office
UH 2.2-m (88-in)	O-IR	28,000 kWh/mo/ 5kW backup generator with two 38-l (10-gal) propane tanks	13 kl (3,513 gal)/ 30 kl (8,000 gal)	A, C	MKOOC[c], IfA outreach
UH 0.6-m (24-in)	O				
UKIRT	IR	53,300 kWh/mo 7 kW backup generator with 76-l (20-gal) diesel fuel tank	14 kl (3,682 gal)/ storage capacity	A, C[a]	MKOOC[c], JAC Outreach
JCMT	SM	37,800 kWh/mo 20 kW backup generator with 8 – 568-l (150-gal) propane tanks	13 kl (3,317 gal)/ storage capacity	A, C[a]	
VLBA	R	29,000 kWh/mo/ 100 kW backup generator with 946-l (250 gal) AST of diesel fuel	No data/ 3.8 kl (1,000 gal)	A, C	MKOOC[c]
Caltech	SM	18,980 kWh/mo/ 30 kW backup generator fueled with propane	7.5 kl (1,992 gal)/ 7.6 kl (2,000 gal), 1,135 l (300 gal)	B	MKOOC[c], CSO Education and Public Outreach

TABLE 4-19. OPERATIONS AND UTILITIES MANAGEMENT ON MAUNA KEA (CONTINUED)

Observatory	Type	Electrical Power Use[a] (Monthly) Backup Generators	Water Use (Monthly)[b] /Storage Capacity	Management Plans and Programs	Outreach and Education Programs
SMA	O-IR	120,000–150,000 kWh/mo no backup generator at present but intend to install a about 500 kW generator with diesel fuel tank	15 kl (3,914 gal)/ 23 kl (6,000 gal) capacity	A, C	MKOOC[c]
W.M. Keck Observatory	O-IR	237,000 kWh/mo 250 kVA backup generator with (2,500-gal) diesel fuel tank	46 kl (12,142 gal)/ 15 kl (4,000 gal), 30 kl (8,000 gal)	B	MKOOC[c]
Hale Pōhaku	N/A	30,000 kWh/mo No backup generator at present	94 kl (25,000 gal)/ 2 x 151 kl (40,000 gal)	A, C	VIS, MKOOC

Sources: CFHT 2004; CSO 2004a; CSO 2004b; Gemini Observatory 2004; Joint Astronomy Center 2004; NASA IRTF 2004; SMA 2004b; Subaru 2004b; UH IfA 2004b; UH IfA 2004d; VLBA 2004

a. HELCO provides electrical power to the Mauna Kea facilities.

b. Potable water trucked in by MKSS and stored in on-site tank.

c. The Mauna Kea Observatories Outreach Committee (MKOOC) coordinates observatory support for the Visitor Information Station at the Ellison Onizuka Center for International Astronomy. This partnership provides education resources for the children, residents, and visitors on the island of Hawaiʻi through programs and outreach activities. See www.mkooc.org for more information.

Acronyms:
IR-Infrared
O-Optical
SM-Submillimeter
R- Radio

Management Plans:

A- Emergency Management Plan
B- Health and Safety Plan
C- Hazardous Materials and Toxic Waste Plan
D- Other Standard Operating Procedures and/or Best Management Practices
*Plan is a section and chapter within the Health and Safety Plan

welding procedure when a slag ignited insulation behind an elevator shaft.

4.2.10.3 Impacts of Reasonably Foreseeable Future Activities on Services

Water Supply. Contractors would truck in domestic water needed on site during the construction phase of future projects. Water needs would increase at Hale Pōhaku to accommodate crews residing at the construction camp.

As shown in Table 4-19, Hale Pōhaku has two 152-kl (40,000-gal) water tanks and typically uses only 95-kl (25,000-gal) per week. The water storage and distribution system is designed to support larger water capacities when needed. During these construction activities, extra water would be trucked to Hale Pōhaku.

The operations of smaller projects (such as the Outrigger Telescopes, the 6-m (20-foot) Testing and Site equipment, and the SMA expansion) and redevelopment projects (such as PanSTARRS and the 1-m (3.3-ft) Class Instructional Telescope) probably would not require additional water tanker trips to Mauna Kea. Current water provisions should support these improvements.

However, larger projects (such as the TMT) would require at least two water storage tanks and a water distribution system as part of its design. Domestic water needs probably would meet or exceed the largest current water user, W.M. Keck Observatory. This would represent a moderate increase in demand for water.

Water supply improvements would be necessary to serve the Humu'ula community on DHHL lands below Hale Pōhaku, depending on the use(s). This would be a logical future source for water trucked to Hale Pōhaku and the summit, instead of sources requiring the long trip from Hilo along Saddle Road.

Electrical Power and Communications. Continued use of existing facilities probably would not increase power needs on the summit. Redevelopment of existing facilities could slightly increase power use, or alternatively could provide more modern and efficient operations. With both possibilities considered, a moderate increase in power needs would be estimated.

Most new development projects listed in Table 4-8 would require new power and communication conduits to be cut from the junction box to the specified sites. Although not all power needs have been calculated for future projects at this time, it is estimated that overall electrical use would not exceed the existing capacity. In conclusion, the expected increase in electrical demand to support the foreseeable future activities within the Astronomy Precinct would result in a small impact on the current electrical system.

Redevelopment projects could reuse existing communications fiber optic lines. This system is relatively new and should support such operations. New development projects would require new fiber optic lines to be installed during the electrical installation process. New fiber optic lines would also be required to connect to antennas added to the SMA site. These additional lines would be a small modification of the current communications system.

Emergency Services and Fire Suppression. It is assumed that the MKSS Emergency Preparedness and Medical Evacuation Plan would be updated to support any future projects. Each new facility would develop an emergency and health and safety management plan and would conduct drills and training. Medical supplies, fire extinguishers, and smoke detectors would be distributed appropriately throughout the facilities.

Additional staff and crews on site during construction and installation activities would increase the potential for an incident to occur. It is assumed that emergency medical technicians would be available. Each worker would be aware of emergency procedures prior to commencing work on the mountain. Hale Pōhaku will continue to be used as an acclimation point.

4.2.10.4 Cumulative Impact Summary

Water Supply. Past, present, and reasonably foreseeable future activities on Mauna Kea have led to the development of a water supply system, which constitutes a substantial impact on water supply. The water usage and traffic associated with water delivery are small and not significant in comparison to overall island water usage and Mauna Kea traffic levels. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have almost no incremental impact.

Electrical Power and Communications. Past and present activities on Mauna Kea have led to the development of electrical power and communications infrastructure, which constitutes a substantial impact on such capability. Reasonably foreseeable future activities are anticipated to have a small additional impact on electrical power and communications. The Outrigger Telescopes Project would have no incremental impact on the existing electrical distribution and communications systems.

Emergency Services and Fire Suppression. Past and present activities on Mauna Kea have led to the development of emergency services and fire suppression capability. It is anticipated that foreseeable future activities would require similar additional development. The addition of the Outrigger Telescopes to the existing observatories on the mountain would have no incremental impact.

4.2.11 Socioeconomics

4.2.11.1 ROI for Socioeconomics

The ROI for socioeconomic resources includes the County of Hawaiʻi. Long-term cumulative effects that could occur would be related to an increase in employment in the ROI. Any economic effects (i.e., increased employment, income, and spending) of the Proposed Action and cumulative activities listed in Tables 4-7 and 4-8 would be expected to last for the duration of construction and operational activities, collectively projected through the end of the Astronomy Precinct lease life, or 2033. Population projections through 2020 generated by the State of Hawaiʻi indicate continued slow growth in Hawaiʻi County, as well as in the State of Hawaiʻi (USDOC 2001b). Table 4-20 provides long-range population projections for the island of Hawaiʻi. Past, present, proposed, or conceptualized projects identified as potentially affecting the socioeconomic condition of the County of Hawaiʻi include the general development of the Astronomy Precinct and observatories on the mountain, jobs created and revenue generated by construction and operation of the observatories, supplemental jobs and revenue generated by future astronomy-industry jobs, and tourism to Mauna Kea.

4.2.11.2 Impacts of Past and Present Activities on Socioeconomics

Since its introduction to Mauna Kea and Hawaiʻi, astronomy has become a local industry has providing substantial economic and educational benefits to the State and local communities. In general, the majority

TABLE 4-20. RESIDENT POPULATION PROJECTIONS FOR THE ISLAND OF HAWAI‘I: 2000 TO 2025

Type of Population and Year	State Total	Hawai‘i
Resident Population (1,000)[a]		
2000	1,197.3	144.6
2005	1,236.1	151.4
2010	1,291.1	159.6
2015	1,349.1	168.3
2020	1,406.2	176.9
2025	1,461.6	187.7
Share of State Population (percent)		
1998	100.0	12.1
2000	100.0	12.1
2005	100.0	12.2
2010	100.0	12.4
2015	100.0	12.5
2020	100.0	12.6
2025	100.0	12.8

Source: USDOC 2001b

a. The resident population is defined as the number of persons whose usual place of residence is in a given area, regardless of the person’s physical location on the date of estimate or census. It includes military personnel stationed or home-ported in the area, but excludes persons of local origin attending school or in military service outside the area.

of the funds used for the construction and operation of observatories on the MKSR were provided by entities outside of the State of Hawai‘i. At least one-third of the funds used for construction were spent on local services, and more than 80 percent of the operating funds were spent in Hawai‘i, mostly within the County. Table 3-11 summarizes the capital costs of the observatories and the number of local residents employed by each facility. The numbers total over $600 million spent and almost 500 jobs created within the County of Hawai‘i (UH IfA 2002a). The W.M. Keck Observatory and Subaru provide the greatest amount of money annually, and the W.M. Keck Observatory provides the most local jobs of the observatories (UH IfA 2002a).

4.2.11.3 Impacts of Reasonably Foreseeable Future Activities on Socioeconomics

Continued operation of the existing facilities would prolong the external operational funding spent within the County and State. Local staff would continue to be employed. Proposed observatory redevelopment would prolong the use of existing facilities, thereby securing future revenue and jobs. Proposed new observatories would increase the amount of operational funding brought into the State and would increase the number of local community members employed. The construction and installation of all future projects would bring additional temporary revenue and jobs to the County and State through materials purchase, equipment rental, and construction crew hiring. It is estimated that the proposed TMT project would double the existing revenue generated by all current observatories together and potentially increase by close to 100 percent local jobs for staff astronomers, engineers, engineering and equipment technicians, software programmers, and administrative personnel (UH IfA 2004e). The State and County economies would benefit further from any increased tourism.

4.2.11.4 Cumulative Impact Summary

In summary, the impact of past, present, and reasonably foreseeable future activities within the Astronomy Precinct on socioeconomics is substantially positive. The Outrigger Telescopes Project would add a small positive increment to this impact. The overall cumulative impact on socioeconomics is substantial and positive.

4.2.12 Air Quality

4.2.12.1 ROI for /Air Quality

The ROI for cumulative impacts on air quality is the entire island of Hawai'i. The emission sources considered in this analysis are those within the MKSR, Hale Pōhaku, and a corridor surrounding the Mauna Kea Access Road and the Saddle Road.

4.2.12.2 Impacts of Past and Present Activities on Air Quality

As discussed in Section 3.1.11.2, air quality on Hawaiʻi is excellent and has remained in attainment status with State and National Ambient Air Quality Standards (NAAQS). Past sources of air emissions in the MKSR have been from short-term construction projects in the area of the summit, vehicles accessing the summit, and fugitive dust along the unpaved portion of the access road or from off-road driving. The development of the mountain has increased traffic to the summit and along the Saddle Road, which has generally increased vehicular emissions and fugitive dust generation. This emission source has steadily increased as the Astronomy Precinct has become more developed and has peaked during construction activities. Initiatives such as closing vehicular access to the Puʻu Poliʻahu jeep trail and paving the upper part of the Mauna Kea Access Road have reduced fugitive dust in the summit area. Air quality has remained within attainment levels.

Volcanic activity is another source of air pollution. These volcanic events emit sulfur oxides and particulate matter into the atmosphere, temporarily elevating pollutant levels across the island. Past volcanic activities have not produced permanent significant impacts on the air quality of the island or the summit area.

Observatory operations generally do not produce air emissions. Minor emission sources include facility maintenance that could emit minimal levels nitrogen oxides.

4.2.12.3 Impacts of Reasonably Foreseeable Future Activities on Air Quality

Proposed activities on the mountain that could potentially affect the air quality within the ROI would be similar to past and present activities. Construction of facilities on Mauna Kea and at the base of the mountain (PTA and Hawaiian Homestead development), general maintenance of these facilities, roadway improvements, and vehicular traffic would be the primary sources of air emissions. These emissions would include nitrogen oxides from vehicle exhaust and fugitive dust. Activities associated with the Army Transformation at PTA would produce long-term dust emissions as described in the EIS for that project (USACE 2004). However, this would be localized below the inversion layer and would not affect the air quality throughout the rest of the ROI.

The reasonably foreseeable future activities within the ROI would not violate SAAQS and NAAQS.

4.2.12.4 Cumulative Impact Summary

Past and present activities within the ROI have had a minor continuing impact on air quality. Foreseeable future activities would have similar impacts. The Outrigger Telescopes Project would employ mitigation measures as discussed in Section 4.1.10.2 and would have a very small incremental impact. Overall, the cumulative impacts to air quality are small.

4.2.13 Noise

4.2.13.1 ROI for Noise

The ROI for assessing noise impacts includes the MKSR and other areas affected by on-site construction, installation, and operations including Hale Pōhaku and vehicle travel routes.

Noise-sensitive receptors within the ROI include cultural practitioners, scientists, staff, recreational users, and other visitors. There are no fixed noise-sensitive receptors, such as residential areas, within the ROI.

4.2.13.2 Impacts of Past and Present Activities of Noise

Past and present activities listed in Table 4-7 have resulted in a small continuous ambient noise level increase within the ROI, attributed primarily to the increase in vehicular traffic associated with these activities. Additional short-term noise increases have occurred as a result of construction and installation associated with the activities listed in Table 4-7. See Section 4.1.12.2 for a discussion of noise impacts associated with construction and installation activities. General operation activities generate inherently low noise levels and make a negligible contribution to the ambient noise level.

The current ambient noise level within the ROI is extremely low; some users of Mauna Kea may be particularly noise sensitive. In particular, cultural practitioners within the immediate vicinity of a noise source could potentially be disturbed. Most disturbances are low level, discrete events rather than a substantial increase in the overall ambient noise level. In general, current noise levels are compatible with existing activities within the ROI. Consequently, noise levels from past and present activities have had a small impact.

4.2.13.3 Impacts of Reasonably Foreseeable Future Activities of Noise

Impacts from the reasonably foreseeable future activities are anticipated to generate noise at levels comparable to those of past and present activities. Construction and installation activities would lead to larger increases in noise levels within the ROI for shorter periods of time. It is anticipated that noise levels would remain compatible with existing activities within the ROI, constituting a small impact. Furthermore, it is anticipated that future construction and installation activities would be consistent with the State of Hawaiʻi community noise standards (Hawaiʻi Administrative Rules, Title 11, Chapter 46).

4.2.13.4 Cumulative Impact Summary

The impact of noise from past, present, and reasonably foreseeable future activities is generally small. The Outrigger Telescopes Project would have no incremental impact. Although individual construction events would continue to produce occasional increased noise levels, overall noise conditions in the ROI would remain low.

4.2.14 Visual/Aesthetics

4.2.14.1 ROI for Visual/Aesthetics

The ROI for assessing cumulative visual impacts is the MKSR and any off-mountain areas from which the Mauna Kea observatories would be visible—such as Hilo, Waimea, and Honokaʻa.

4.2.14.2 Impacts of Past and Present Activities on Visual/Aesthetics

The astronomy facilities at the summit of Mauna Kea have become a prominent, and to many Native Hawaiians notorious, feature. At least some of the observatories are visible from most locations within the MKSR and from many off-mountain locations including Hilo, Waimea, and Honoka'a. In particular, the summit ridge observatories (UKIRT, UH 2.2-m, Gemini North, and CFHT) are visible from Hilo; IRTF, the W.M. Keck Observatory, and Subaru are visible from Waimea and Honoka'a. The observatory structures are white or silver to minimize internal temperature variations which can affect seeing quality. Whereas most of the observatory structures are curved domes, Subaru has an unusual paneled structure that renders it less visible much of the day. However, Subaru appears extremely bright at sunset from off-mountain locations where it is visible owing to specular reflections of sunlight from its flat surfaces.

Although not within the specific ROI for visual impacts, the Hale Pōhaku Mid-Elevation Support Facilities were constructed with design restrictions. These structures were sited and constructed to follow mountain contours and colored to blend with the surrounding natural features and terrain.

4.2.14.3 Impacts of Reasonably Foreseeable Future Activities on Visual/Aesthetics

In general, reasonably foreseeable future activities with the greatest potential for visual impact would be those that involve development of a previously undeveloped site. The principal such project is the TMT, which is being considered for a site on the northwest plateau. This location would take advantage of a northerly extension of the summit ridge to entirely block views on the new facility from Hilo and partially block views from Honoka'a (Master Plan 2000). Redevelopment of an existing facility would have a small to minimal visual impact as long as the basic frame of the structure remained unaltered. Any modifications would follow design guidelines specified in the 2000 Master Plan limiting size, color, and surface materials so as to minimize the observatory's visual impact. All future projects will be reviewed by the Design Review Committee for adherence to these guidelines prior to approval (UH 1999).

Construction activities on the mountain can create a local visual impact from dust, trash, and equipment. It is expected that dust and trash will be minimized throughout construction phases on all future projects on Mauna Kea through appropriate management plans which include dust and trash controls. All construction equipment would be removed from the site and the mountain after construction is completed.

4.2.14.4 Cumulative Impact Summary

The visual impacts of past and present astronomy-related activities in the MKSR have been substantial. Future visual impacts may be minimized by new design guidelines and careful site selection of new development projects. Mitigating dust generation, enforcing strict trash control, and minimizing on-site staging areas would reduce local short-term visual impacts. The Outrigger Telescopes Project would add a small incremental visual impact. Overall, the cumulative visual impact from past, present, and reasonably foreseeable activities is substantial.

4.2.15 Cumulative Impacts of End of Lease

As a reasonably foreseeable future astronomy project, End of Lease in 2033 could result in a variety of outcomes and, thus, its precise nature is unclear at this time. Two bounding scenarios will be addressed for the purposes of this cumulative impact analysis:

(1) All observatories (i.e., those currently existing and the reasonably foreseeable future projects) would continue operation beyond 2033; and

(2) All observatories operating on Mauna Kea as of 2033 would be decommissioned and completely removed from the mountain.

4.2.15.1 Continued Operation of All Observatories Beyond 2033

This scenario assumes that all environmental protection and mitigation measures required for operation of the Mauna Kea observatories including the reasonably foreseeable future astronomy projects undertaken prior to 2033 would continue beyond that point in time. The impacts of continued operation of all observatories on Mauna Kea beyond 2033 would be similar to the cumulative impacts that have been addressed throughout Section 4.2. Continued operation of the observatories would have little to no adverse incremental impacts on solid wastes and hazardous waste management; geology, soils and slope stability; land use and existing uses; transportation; utilities and services; air quality; flora and fauna; the Wēkiu bug and its habitat; hydrology and water quality; and noise through the indefinite future beyond 2033. The incremental impacts of the Outrigger Telescopes Project would remain a minor contributor.

The principal cumulative environmental impacts resulting from continued operation of the observatories beyond 2033 would largely be on cultural resources and visual/aesthetics. The cumulative impact on cultural resources was addressed in Section 4.2.3 where it was noted that the impact of past and present astronomy and related projects has been adverse substantial, and the cumulative impact associated with operation of the existing observatories and reasonably foreseeable future astronomy projects is anticipated to be adverse and substantial. Thus, continued operation of the astronomy facilities beyond 2033 would, in turn, continue to be substantial and adverse. Cultural resources and associated uses would continue to share the mountain with astronomy and other uses such as recreation and tourism. The incremental impact of the Outrigger Telescopes Project would continue to be a minor contributor to this overall cumulative impact beyond 2033.

The cumulative impact on visual/aesthetics associated with astronomy on Mauna Kea was addressed in Section 4.2.14. The substantial cumulative impact of past, present, and reasonably foreseeable future astronomy projects would continue. It would vary in intensity depending upon the viewing location and the viewer. The incremental impact of the Outrigger Telescopes Project would represent a minor contributor to the overall cumulative impact of the Mauna Kea astronomy facilities on visual/aesthetics.

With respect to socioeconomics, operation of the existing and reasonably foreseeable future observatories beyond 2033 would continue to have substantial and positive impacts on the local and State economies, employment, and education. Currently the observatories support about 500 jobs (see Section 3.1.10). Employment levels in 2033 and beyond would probably be greater, particularly when development and operation of the TMT on Mauna Kea is considered. By 2033 it is reasonable to assume that the total economic activity generated by the observatories would exceed the inflated equivalent of the approximately $130 million/yr currently flowing into the County of Hawai'i and the inflated equivalent of the approximately $140 million flowing to the State. Indirect employment within the County and the State generated by observatory expenditures would also continue beyond 2033. Mauna Kea would remain the premier ground-based astronomy location in the world and Hawai'i would continue to attract the best astronomers and astronomy research projects. The educational opportunities for students at all levels to learn in such an atmosphere would continue as would the community-based programs conducted and supported by the observatories. The incremental impact of the Outrigger Telescopes Project would continue to be a small and positive part of the substantial beneficial cumulative impacts of continued observatory operation on socioeconomics beyond 2033.

4.2.15.2 Decommissioning and Demolition of All Observatories

For this End of Lease 2003 scenario, the general assumptions for the reasonably foreseeable future astronomy projects noted in Section 4.2.2 pertain. The following additional assumptions have also been made:

- The observatories, support facilities, and underground structures, exclusive of the Mauna Kea Access Road and the Hale Pōhaku Mid-Elevation Support Facilities, would be dismantled, demolished, and completely removed from the mountain.
- Explosives would not be employed in accomplishing the demolition. Each facility would first be stripped of recyclable materials; mechanical methods (e.g., wrecking balls, jack hammers) would be employed to demolish the existing structures.
- There is not enough surplus cinder on Mauna Kea at present, nor would enough cinder be produced during dismantlement, demolition, and removal, to restore the pre-observatory topography of the observatory sites; each site would be left in a neat and tidy condition with adequate drainage controls installed to preclude erosion at the abandoned sites.
- Environmental protection and mitigation measures similar to those that would be employed for the Outrigger Telescopes Project (e.g., dust controls and protection of Wēkiu bug habitat) would be an integral part of all approved observatory removal plans.
- Decommissioning and demolition of all of the observatory facilities would take place over a number of years to avoid overburdening the contractor work force, road capacities, the Hale Pōhaku facilities, and other support facilities such as the construction staging areas. Phased implementation would lessen the impact on other resources and uses of the mountain such as cultural practices and recreation. The principal cumulative impacts would be experienced primarily in the areas of cultural resources, biological resources,

transportation, socioeconomics, visual aesthetics, noise, and solid waste.

Cultural Resources. Dismantling, demolition, and removal of each observatory facility would have to be accompanied by appropriate measures to protect known cultural resources and nearby sites. Each demolition project would have to plan for and accommodate the possibility of encountering heretofore undiscovered sites during removal of foundations and underground structures. Given that each of the observatories would be located on previously disturbed sites, known cultural resources should not be directly or adversely impacted by the dismantlement, demolition and removal of each observatory. The possibility exists that ground vibrations from demolition equipment such as jack-hammers and wrecking balls could impact the stability of physical resources such as shrines in nearby areas and would have to be considered during development of demolition plans and techniques.

Overall, with reasonable care and planning, any adverse impacts to physical sites should be small and not significant. The presence of large demolition equipment and heavy trucks on the observatory sites and along the Mauna Kea Access Road, and demolition activities themselves, would substantially and adversely impact cultural practices. This would occur throughout the relatively lengthy period required to remove all of the observatories and support structures, after which this source of adverse impact would cease. When all observatories have been removed from the mountain, the cumulative adverse impact to cultural resources would be greatly reduced. However, given that restoration of pre-observatory topography at each of the former sites is not considered feasible at this time, reduced but still substantial adverse cumulative impact on cultural resources would persist. The incremental impact of removing the Outrigger Telescopes Project would be a small contribution to the overall change in cumulative impact on cultural resources.

Biological Resources. Dismantlement, demolition, and removal of the observatories within or near areas of Wēkiu bug habitat has the potential to adversely impact some biological resources. It is unlikely that flora at or near the demolition sites would be subject to long-term adverse impacts. The former observatory sites will already have been disturbed by facility construction and operation, thus little flora would be directly impacted by on-site demolition activities. Nearby flora may be subject to fugitive dust. However, with careful attention to dust control measures, these resources should experience only small to negligible impacts.

Potential impact to Wēkiu bugs is less clear. Some Wēkiu bug habitat may experience ground vibration during the demolition phase of observatory removal. It is not known what effect, if any, intense and prolonged vibration of the habitat would have on the resident Wēkiu bugs or on habitat suitability. This may have to be carefully monitored during observatory removal. Removal of the Outrigger Telescopes Project, particularly the retaining walls at JB-5 and Outrigger Telescope 3, and the removal of Outrigger Telescope 1 could have substantial adverse impact on Wēkiu bug habitat in nearby areas. Removal would have to be carefully planned and suitable mitigation measures instituted to prevent sidecasting of cinder and destabilizing the cinder slope in these areas. Potential impacts to the Wēkiu bug and its habitat may be lessened if removal plans for the Outrigger Telescopes and other observatories accommodate leaving retaining walls in place. Biological resources in the areas of Hale Pōhaku and the construction staging areas near Hale

Pōhaku and the summit should not be substantially impacted by observatory removal. Other fauna near the observatory sites should not be adversely impacted.

Transportation. It is likely that mobilization and demobilization of contractor heavy machinery and workforces would occur a number of times over the period of phased observatory removal. In addition to transporting the heavy demolition machinery that would be needed at each removal site, heavy truck and water tanker traffic would increase on the Mauna Kea Access Road throughout the observatory removal process. There would be a further increase in traffic due to demolition crews commuting to and from the summit. Heavy trucks would be needed to remove the demolition debris from each observatory site and transport that debris to licensed disposal sites elsewhere on the island. The addition of a relatively large amount heavy truck and tanker traffic on the access road would at times adversely impact other traffic (e.g., recreational users, tourists, cultural practitioners), causing some delays and possibly increasing accident risks. This is likely to persist throughout the extended period required to complete the removal of all observatories. Heavy truck and equipment traffic throughout the observatory removal process would also adversely impact the Mauna Kea Access Road, leading to a requirement for increased maintenance. It is likely that Saddle Road improvements would have been completed well in advance of 2033. Thus it is unlikely that traffic on that road would be adversely impacted by the heavy truck and other traffic associated with observatory removal-. Overall, the cumulative impact on transportation on the Mauna Kea Access Road during demolition would be substantial, adverse, and significant. The incremental impact associated with removal of the Outrigger Telescopes Project would be a small contributor to the cumulative impact on transportation.

Socioeconomics. Substantial, adverse, and significant socioeconomic impacts on the local and State economies, employment, and education would occur with cessation of astronomy on Mauna Kea and removal of the observatories. As noted in 4.2.15.1 the State and local economies benefit from the over $270 million/yr flowing into the economies. This amount would likely increase between now and the year 2033, but would cease with this End-of-Lease outcome. The 500 long-term jobs created by astronomy on Mauna Kea along with many of the indirect jobs associated with astronomy would also cease. Many of those jobs are in highly skilled occupations that would be lost from the local and State job bases. Some of those jobs would be replaced in the short-term by job opportunities created by observatory removal activities. However, those jobs would end with completion of removal. The educational opportunities available to Hawaiians and Hawaiian students because of the presence of a large group of astronomers and world-class facilities would cease, as would the community programs conducted by the observatories. Mauna Kea would no longer be one of the world's premier locations for astronomy. The activities at Mauna Kea would probably move to locations elsewhere in the world. In addition, with astronomy no longer funding support activities on Mauna Kea, other funding sources would have to be found for activities such as maintenance of the Mauna Kea Access Road, operation of the Hale Pōhaku facilities, and the ranger force and cultural interpreters. The incremental impact of removing the Outrigger Telescopes Project would be a small contributor to the overall substantial, adverse, and significant cumulative impact on socioeconomics from observatory removal.

Visual/Aesthetics. While the observatories are being removed, the impact on viewscapes from those areas on Mauna Kea where the observatories can be seen would be adverse, substantial and significant due to the presence of heavy equipment and demolition rubble. This would be the case for the duration of the removal activities. Observatory removal activities would also be somewhat visible from some off-mountain areas such as Hilo, Waimea, and Honokaʻa. With completion of observatory removal, the abandoned sites, while neat in appearance, would likely still show signs that they had been the locations of large structures. It is unlikely that the original topography of each of the observatory sites could be fully restored. Although greatly reduced from present levels, the visual impacts would likely remain moderate to substantial for viewers in the area of the summit. Completion of observatory removal would continue to have a small residual adverse visual impact from some off-mountain locations.

Noise. Removal of the observatories would also generate localized intense and sustained noise from demolition activities (e.g., wrecking balls and jack hammers) and the heavy equipment and associated traffic. This noise would be superimposed on an existing environment that is characterized by very low noise levels. It is expected that even with contractor compliance with OSHA standards and State of Hawaii Community Noise Standards, noise impacts during demolition would be substantial, adverse, and significant. The incremental impact associated with removal of the Outrigger Telescopes Project would be a small contributor to the cumulative noise impact associated with removal of the observatories. After observatory removal there will be a residual small to moderate adverse noise impact from recreational and other non-observatory users of the mountain.

Solid Waste. During observatory removal there should only be a minor adverse impact from solid waste on the summit if proper waste containers are used and effective housekeeping practiced by the removal contractors. There should be no to negligible impact from solid waste during transportation of demolition debris down the mountain if suitable mitigation measures, such as covering the debris with a tarp during hauling, are implemented. Because of the number and sizes of the observatories on Mauna Kea, demolition and removal would generate an extremely large amount of solid waste. While some of this material could be recycled, it is anticipated that a very large fraction would be disposed of at existing landfills. It is anticipated that removal of the observatories could have a substantial and adverse effect on landfill capacity.

Other Resources. Air emissions during removal of the observatories would be unlikely to exceed the SAAQS or the NAAQS and should result in a moderate, but not significant, impact on air quality. The incremental impact associated with removal of the Outrigger Telescopes Project would be a small contributor to the cumulative impact on air quality. Careful attention to appropriate dust control measures by the demolition contractors would preclude fugitive dust from significantly impacting local air quality or other resources.

Geology would not be impacted but slope stability could be adversely impacted, particularly in those areas where retaining walls and other slope stabilization measures had to be installed during construction of the observatories. The removal of these structures from observatory sites would have to be carefully planned and implemented to prevent destabilization of slopes and eliminate potential for impacting existing Wēkiu bug habitat, for example at JB-5 and Outrigger Telescope 3. The incremental impact associated with removal of the Outrigger Telescopes Project would be a small contributor to the overall cumulative impact on geology and slope stability.

Hazardous waste management associated with removal of the observatories should not result in adverse environmental impact, given attention to use of proper waste containers and effective housekeeping practices by the removal contractors. Minimization of hazardous material storage and use at each work site, combined with adequate contractor spill control and response planning, should help ensure that no impacts would arise from these activities.

The currently designated land use for the Astronomy Precinct would no longer be necessary and could be revised accordingly. Existing uses of the mountain such as cultural practices, recreation, and tourism would be substantially and adversely impacted during observatory removal. Heavy truck activity, noise, and the need to establish exclusionary zones around demolition sites for safety purposes would contribute to these impacts. Over the long-term, tourism may experience a large decline with cessation of astronomy as an attraction. Utilities and services in the summit area could also be adversely impacted with removal of the observatories. Electric service to the summit would no longer be needed and would probably be decommissioned or removed. The substation at Hale Pōhaku would no longer be needed and could also be removed. The communication lines to the summit might be retained for use in emergencies.

For these environmental resources, the incremental impact associated with removal of the Outrigger Telescopes Project would be a negligible to small contributor to the overall cumulative impacts.

4.2.16 Cumulative Impacts Conclusions

From a cumulative perspective, the impact of past, present, and reasonably foreseeable activities on cultural and biological resources is substantial, adverse, and significant. The corresponding impact on socioeconomics is substantial and positive. In general, the Outrigger Telescopes Project would add a small incremental impact. Overall, past, present and reasonably foreseeable future actions have a significant impact on the quality of the human environment.

4.3 POTENTIAL ENVIRONMENTAL IMPACTS OF THE CANARY ISLANDS SITE ALTERNATIVE

NEPA and the Council on Environmental Quality (CEQ) implementing regulations apply to proposed Federal agency actions that may occur in or have environmental effects on the United States, its territories, and possessions. The Gran Telescopio Canarias (GTC) alternative site is located on the island of La Palma, Canary Islands, and is under the control of Spain. As a result, NASA need not comply with NEPA if it were to decide to locate the Outrigger Telescopes Project at the GTC alternative site. Rather, NASA must satisfy the requirements of Executive Order (EO) 12114, Environmental Effects Abroad of Major Federal Actions, prior to taking a final action concerning the GTC alternative.

While the purposes of NEPA and EO 12114 are very similar, there are far fewer procedural requirements under the Executive Order and the scope is much narrower. EO 12114, Subsection 2-3 describes the Federal actions covered by the Executive Order that necessitate the preparation of environmental documentation to be considered by the decision maker before reaching a final decision. The actions specifically covered are:

"(a) major Federal actions significantly affecting the environment of the global commons outside the jurisdiction of any nation (e.g., the oceans or Antarctica);

(b) major Federal actions significantly affecting the environment of a foreign nation not participating with the United States and not otherwise involved in the action;

(c) major Federal actions significantly affecting the environment of a foreign nation which provide to that nation:

(1) a product or physical project producing a principal product or emission or effluent which is strictly prohibited or strictly regulated by Federal law in the United States because its toxic effects on the environment create a serious public health risk; or
(2) a physical project which in the United States is prohibited or strictly regulated by Federal law to protect the environment against radioactive substances.

(d) major Federal actions outside the United States, its territories and possessions which significantly affect natural or ecological resources of global importance designated for protection under this subsection by the President, or, in the case of such a resource protected by international agreements binding on the United States by the Secretary of State.…"

If a proposed Federal action falls within one of the above categories, the Federal agency must prepare either an environmental impact statement (EIS), a bilateral or multilateral environmental study, or a concise review of the environmental issues involved (including an environmental assessment, summary environmental analysis, or other appropriate document) depending on which category is applicable. An EIS is only required for an action falling under Subsection 2-3(a) (i.e., significant effects on global commons), and is discretionary for actions falling under Subsection 2-3(d) (i.e., significant effects on natural or ecological resources of global importance). It should also be noted that "actions not having a significant effect on the environment outside the United States as determined by the agency" are exempt from EO 12114 (see Subsection 2-5 (a)(i)).

While not necessarily required under EO 12114 to support a decision on the GTC alternative site, NASA has conducted an environmental analysis on the GTC site sufficient for a decision maker to make a meaningful comparison of the potential environmental impacts of siting the Outrigger Telescopes Project at the Mauna Kea and GTC sites. For purposes of analysis and comparison the ROI for each environmental medium relevant to the GTC site is generally the same as that for the Proposed Action on Mauna Kea. However, there is no equivalent to Hale Pōhaku along the road to the GTC site.

4.3.1 Cultural Resources

The earliest known inhabitants of the Canary Islands are a people who have come to be known as Guanches. This people is thought to have originated from the Berbers of the Atlas region in Africa (modern day Morocco). There appears to be no group or sub-population that considers the area within the Roque de los Muchachos Observatory (ORM) (an area that includes the GTC) to be sacred or of religious importance. However, there are a number of archeological sites along the rim of the caldera. The GTC has been surveyed for potential archeological properties to the extent necessary to accommodate the observatory and ancillary facilities. As a part of the environmental assessment for the GTC, there are 7 sensitive archeological sites that are protected and/or will be relocated as a part of the construction effort. These sites are to be protected and/or relocated in accordance with Spanish regulatory requirements. The presence of these sites has not impeded construction. See Figure 4-5. The GTC site appears located at the 2,270-m (7,450-ft) contour at the ridge line denoted by the square denoted by Caseta.

On-site and Installation Impacts. Since there are no groups that consider the ORM to be sacred or of religious importance, on-site construction and installation will have no impact on traditional cultural values. The GTC site has been surveyed for archeological sites to the extent necessary to construct and operate the GTC. Certain configurations of the Outrigger Telescopes could be placed entirely within the zone that has been screened for archeological properties. However, from a scientific standpoint, the most advantageous configuration would likely involve the Outrigger Telescopes placed so as to "surround" the 10-m (33-ft) GTC telescope. In that event certain Outrigger Telescopes would likely be placed in areas not previously surveyed for archeological properties. For that scenario additional archeological surveys would be required. Based on prior GTC and other ORM telescope experience, there is a reasonable likelihood that one or more additional archeological sites would be discovered. However, again based on prior experience, suitable mitigation is likely available without undue effect on the siting and construction of the Outrigger Telescopes. In summary, the anticipated impacts on cultural resources are minor.

Operations Impacts. Since there is no traditional cultural value placed on the ORM or surrounding areas, operation of the Outrigger Telescopes would not impact traditional cultural values. Similarly, once the on-site construction and installation phases are completed, there is no potential for adverse effect on archeological resources. The anticipated adverse impact on cultural resources is zero.

Mitigation Measures. If the proposed layout of the Outrigger Telescopes places any of the telescopes in previously unsurveyed areas, an archeological survey would be conducted. If any archeological resources of consequence are discovered, NASA would ensure that all stipulations and conditions specified by Spanish authorities would be carried out.

4.3.2 Biological Resources and Threatened and Endangered Species

The area surrounding the GTC site is populated with a subalpine ground cover composed of mountain scrub that is easily damaged by foot or machinery traffic. There have been no protected plant species identified in the area surrounding the GTC. The only fauna species that is "of special interest" that may be encountered in the ORM is the vulgar kestrel (Falco tinnunculus), although no nesting sites were encountered in the environmental survey of the GTC site.

Los Tiles, which extends over four municipalities of La Palma, is a component of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) world network of Biosphere Reserves. Such reserves combine conservation of the natural environment with research and environmental monitoring, while balancing the need for sustainable development.

The island of La Gomera, approximately 80 km (50 mi) southeast of La Palma, is home

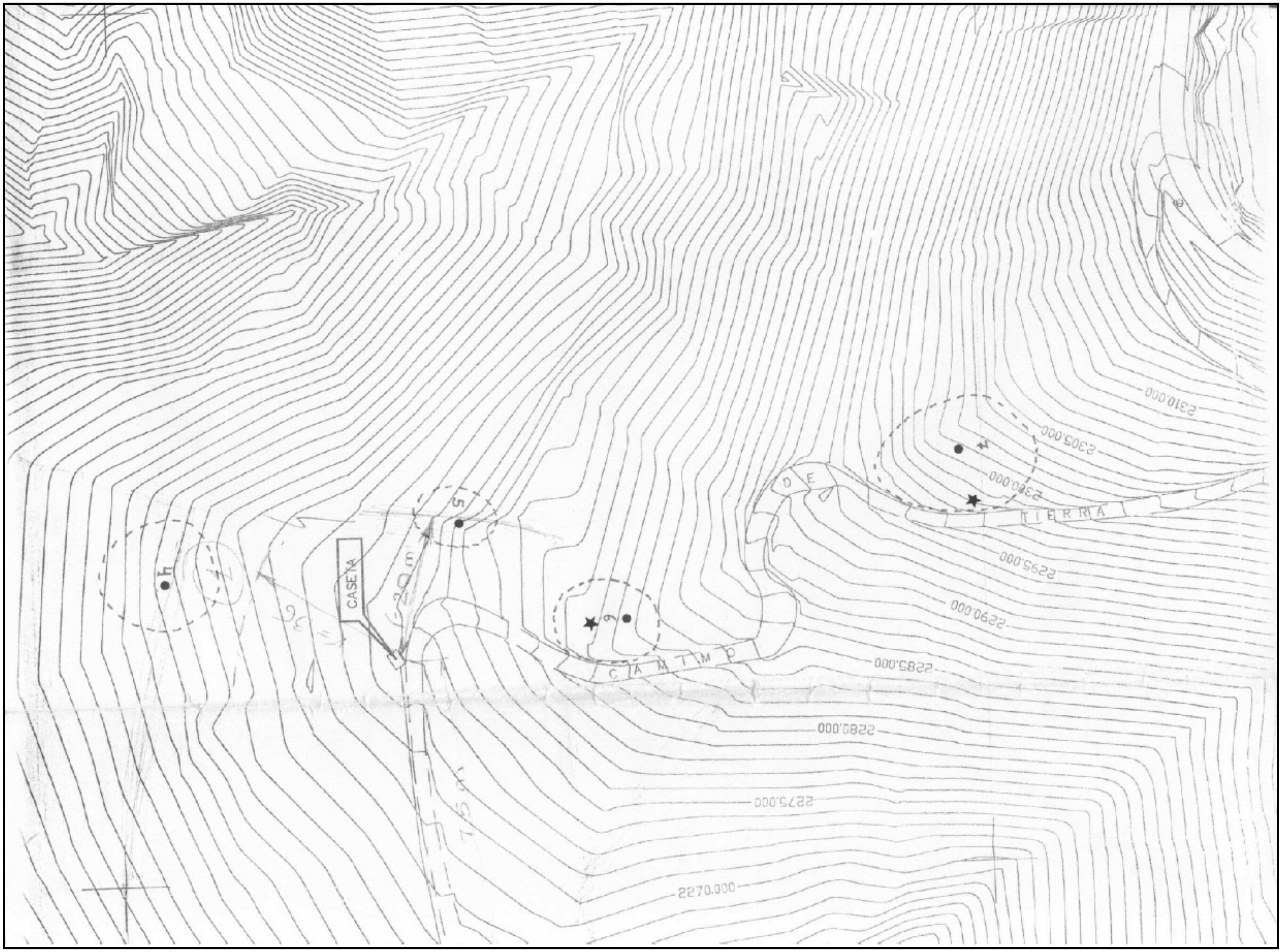


FIGURE 4-5. ARCHAEOLOGY MAP

to Garjonay National Park, which is a World Heritage site. World Heritage sites are places in nature and culture with a value and importance reaching far across geographical and political boundaries and are a heritage of the world in general. The Grand Canyon of the Colorado River, Galapagos Islands, and Taj Mahal are prominent examples of properties on the World Heritage list. The concept of World Heritage sites was first implemented by UNESCO in 1972, with new properties of nature and culture considered exceptional added to the list yearly. Garjonay National Park, almost 4,000 ha (10,000 ac) in size, is located in the center and highest part of La Gomera. The main purpose of creating this National Park was the protection of its exceptional vegetation, especially its bay-tree forests. Hardly any of these forests remain in the world, and they are a veritable relic of the past. In Garjonay National Park, 450 different plant species have been identified so far. Thirty-four of them are exclusive to La Gomera, while 8 of these are only found in the National Park. There are two species of mountain doves only found in the Canary Islands. In addition, early research indicates that among the numerous invertebrate species are several species that are only found locally.

On-Site Construction and Installation Impacts. A sizeable area adjacent to the GTC has been disturbed by material staging and construction activities. The relative impact of the Outrigger Telescopes Project would depend on the location of these telescopes in relation to the GTC. While it may be feasible to locate them wholly in previously disturbed areas, from a science and research perspective the optimal configuration would likely be similar to that on Mauna Kea (the Outrigger Telescopes placed in a configuration surrounding the GTC). Such a configuration would involve siting of some telescopes in previously undisturbed areas, leading to destruction of flora. Because of the nature of the site and flora involved, there would be difficulty in flora reestablishing itself. However, the relatively small size of the Outrigger Telescopes would necessarily limit the area of disturbance.

Animals temporarily may leave the immediate vicinity during the period of construction and installation. Noise may cause a startle response among certain species, although no bird nesting sites have been found in the vicinity of the GTC. It is reasonable that animal species would return after on-site construction and installation are complete.

The 1999 environmental survey for the GTC resulted in a finding of no impact to protected species within the GTC area. Since construction and installation activities associated with the Outrigger Telescopes would be similar to but smaller in scale than the GTC, no impact to protected species is anticipated.

Because of the localized nature of this construction and installation activities, there would be no biological impact on the Biosphere Reserve or on the World Heritage site of La Gomera.

In summary, the impact on flora and fauna would be minor. Impacts of fauna would be temporary, while it could take some period of time for flora to reestablish itself.

Operation Impacts. Operation of the Outrigger Telescopes would generate very little noise and little overall human activity. Human activity would be confined to the developed portion of the GTC site. Biological impact would be zero.

Mitigation Measures. During on-site construction and installation, a construction best management plan (BMP) would be implemented that would be similar to that proposed for Mauna Kea. These practices would further limit impact to flora and fauna.

4.3.3 Hydrology, Water Quality, and Wastewater

No surface or subterranean water courses or aquifers cross the site. The GTC will use a septic tank and leech field to dispose of domestic wastewater.

On-Site Construction and Installation Impacts. There would be three principal sources of environmental impact during construction: (1) use of water for dust control, (2) accommodating the water supply and wastewater treatment and disposal needs of construction workers, and (3) alteration of runoff in previously undisturbed areas. Water would be trucked to the site. For purposes of analysis, it is assumed that water use would be roughly equivalent to that at Mauna Kea. While there may be more workers at certain time as at the site than under the Mauna Kea alternative, the large proportion of them would likely commute daily rather than reside near the construction site. This is in contrast to the Mauna Kea alternative where many workers may temporarily reside at Hale Pōhaku. The septic system and leech field at GTC have been approved by local authorities.

Some of the water applied for dust control would be lost to evaporation and the remainder would percolate downward. Since water action has resulted in two soil layers where the cinder has taken on a clay-like character, it is possible that there may be horizontal displacement of water while percolating downward. Otherwise, the percolation process should be similar to that on Mauna Kea. Minor hydrologic impact from dust control would be expected.

The presence of construction workers at the GTC site for Outrigger Telescope construction and installation would add domestic wastewater loading to the septic system, although within the capacity of the system. As an alternative, portable toilets with off-site disposal could be used. Impact from domestic wastewater on hydrology and water quality is expected to be small.

While construction activities may affect precipitation run-off from the site, it is anticipated that impacts to hydrology and water quality would be small. No water channels or drainages cross the site.

Operation Impacts. Potential impacts are limited to those arising from the generation of domestic wastewater. All personnel working on the Outrigger Telescopes during operations would use the GTC facilities. The number of such personnel would be very small. Mirror cleaning and resurfacing would be accomplished on site, with the wastewater collected, placed in containers and transported off site. The overall impact would be effectively zero.

Mitigation Measures. Implementation of a BMP would minimize alteration of drainage. Disposal of wastewater through use of septic systems and leech fields has been approved and of no particular concern for astronomy activities in the ORM. However, there is a Canary Island-wide concern over potable water source protection and enhancement. Such concerns arise from (1) increased population, and (2) local rainfall being the only source for potable water. While there is no current pressure to upgrade wastewater facilities at the observatories, it is conceivable that additional island-wide requirements could be imposed within the next several years. There also conceivably could be pressure for observatories at the ORM to collect some of the precipitation for on-site use.

4.3.4 Solid Waste and Hazardous Materials Management

On-Site Construction and Installation Impacts. The analysis of these impacts and mitigation measures for the W.M. Keck Observatory site in Section 4.1.5.2 generally applies to the GTC alternative. However, the mitigation applicable to the Wēkiu bug would not be relevant and, thus, not implemented. There would be a minor increase in solid waste but no impact with implementation of appropriate mitigation measures. With appropriate handling of hazardous materials, there would be effectively no impact arising from such materials.

Operation Impacts. The analysis of these impacts and mitigation measures described in Section 4.1.5.2 for the W.M. Keck Observatory site would generally apply to the GTC alternative. Operations at the GTC site would result in effectively no increase in hazardous materials use and disposal or solid waste.

4.3.5 Land Use and Existing Activities

Land Use Impacts. The GTC alternative site lies within the ORM which is a designated area within the National Park of the Caldera of Taburiente. By law astronomy activities have been declared compatible with traditional uses of the grounds within the ORM. Thus on-site construction, installation, and operation of the Outrigger Telescopes would be compatible with and not adversely affect land use designation.

Existing Activities

<u>On-Site Construction and Installation Impacts</u>. Activities associated with the on-site construction and installation of the Outrigger Telescopes Project would occasionally delay vehicular traffic along the northern road route to the ORM and temporarily increase noise levels and dust generation. See sections related to transportation (Section 4.3.8), noise (Section 4.3.12), and air quality (Section 4.3.11) impacts for additional information. Tourism activities primarily concentrated on the south rim of the caldera would not be affected. See Section 4.3.13 for more information on visual impacts. There are no activities of any note in the area of ORM other than astronomy, other than a relatively small number of tourists.

<u>Operation Impacts</u>. The Outrigger Telescopes Project would be consistent with the only use of any note, astronomy, in and in the vicinity of the ORM. There would be no impact.

4.3.6 Geology, Soils, and Slope Stability

The GTC site may be characterized as a broad plain sloping 18 percent downward towards the northwest. The upper 1 to 3 m (3 to 10 ft) of the surface soil is clay-like due to weathering. This layer has low compressive strength. Below this is a layer of basaltic lava 1 to 6 m (3 to 20 ft) thick that exhibits substantially higher bearing capacity. Beneath this layer is another stratum that also exhibits extreme weathering and low load bearing capacity.

On-Site Construction and Installation Impacts. The altered state due to weathering of the volcanic material in the upper soil layers results in a surface subject to erosion as a result of project related activities. Careful design would be implemented to ensure that the Outrigger Telescopes are placed on stable foundations. The BMP will need to include measures to minimize erosion. Such measures would likely need to be more extensive than at the W.M. Keck Observatory where the Outrigger Telescopes locations would be almost entirely on previously leveled land. Still with available mitigation methods the adverse impacts to soils and slope stability are anticipated to be small.

Operation Impacts. Given the nature of Outrigger Telescope operations, adverse impacts would be zero.

4.3.7 Geologic Hazards

Earthquakes are very rare in the Canary Islands. Volcanic eruptions have occurred recently on the southern end of La Palma. There have been eight eruptions since 1470. The Spanish building code assigns the ORM area its lowest level of seismic risk and very low ground motion coefficient.

Outrigger Telescopes Impacts. On-site construction, installation, and operation would have no adverse impact on seismic and volcanic activity.

4.3.8 Transportation

Within the ORM, the road the GTC is two-way and entirely paved. The ORM itself is accessible via two routes, both of which are paved for their entire lengths. The southerly and more direct route from Santa Cruz de la Palma provides access through the National Park of the Caldera of Taburiente to the developed viewing points for tourists of the caldera. However, this route has many curves and precipitous sections. The longer and more forgiving route entails a circuitous route around the northern end of the island. While tourism is growing among the eastern islands of the Canaries, tourism is still not a major factor on the agriculturally based island.

On-Site Construction and Installation Impacts. The anticipated amount and mix of construction traffic during the on-site construction and installation stages would be roughly the same as for the Proposed Action. Therefore, one would expect the environmental impacts to be essentially the same with some exceptions. Since both routes to the ORM are entirely paved, there would be less dust generation for the GTC alternative. Also, since traffic can use two routes to the ORM and visitor activity is relatively small, there is likely to be much excess traffic capacity. Finally, movement of the largest components (e.g., telescopes and domes) would likely follow the northern route, and thus not delay the larger portion of tourist traffic to the southern edge of the caldera. Overall adverse transportation impact would be small and less than at Mauna Kea.

Operation Impacts. Even using a conservative assumption of 6 to 12 daily roundtrips, adverse transportation impact would be nearly zero. There are two routes to the ORM and no evidence that collectively these roads are heavily traveled.

Mitigation Measures. As for the Proposed Action, movement of large and over-sized loads along the circuitous northern route would be planned and coordinated to minimize traffic delays.

4.3.9 Utilities and Services

Water Supply and Communications. The analysis of impacts on water supply and communications in Section 4.1.9.2 for the W.M. Keck Observatory site is equally applicable to the GTC site. No on-site construction, installation, or operations impacts would occur.

Electrical Power. The primary feed is from a substation at about the 1,000 m (3,300 ft) level. This line runs mostly overhead to the vicinity of the ORM and GTC and then underground for the last 2 km (1.2 mi). The GTC itself has a feeder line that has a capacity of 1 megawatt, with an anticipated load of no greater than 850 kW. The GTC will have emergency generator capacity of 969 kW.

On-Site Construction and Installation Impacts. The analysis for the W.M. Keck Observatory site in Section 4.1.9.2 equally applies to the GTC alternative. There will be no adverse impact on electrical power.

Operation Impacts. Four Outrigger Telescopes would require 120kW, and six would require 180 kW. When combined with the anticipated load of the GTC itself, the maximum load would be either very near to or exceed capacity. The situation would be even more problematic for emergency generation. It is quite likely that capacity of the feeder line would need to be increased with attendant changes of equipment and potentially the need to install a new feeder line. An additional emergency generator is even more likely to be needed with accompanying expansion of on-site infrastructure. Overall adverse impact to electric power capacity would be substantial without the upgrades. With such additional infrastructure, the adverse impact would be small.

Emergency Services and Fire Suppression. The GTC facilities store about 30,000 l (7,900 gal) of water for fire suppression. There are four helipads within several hundred meters of the GTC. Thus, persons needing emergency treatment could be airlifted to the nearest hospital in Garafia at the northern base of the mountain.

Impacts on Emergency Services and Fire Suppression. The analysis for the W.M. Keck Observatory site provided in Section 4.1.9.2 equally applies to the GTC site. No adverse impacts are anticipated.

4.3.10 Socioeconomics

Excluding the need to add certain facilities at the GTC site that presently exist at the W.M. Keck Observatory (e.g., an interferometer and associated equipment, electric power upgrades, etc.), on-site construction, installation, and operations costs would be approximately the same: $13 million for on-site construction and installation and $5 to $7 million yearly for operations. The only difference would be slightly less expenditures on La Palma for construction due to labor costs that are essentially counterbalanced by higher transportation costs to deliver certain components (e.g., telescopes and domes) to La Palma. There would relatively be a greater socioeconomic benefit to La Palma and the Canary Islands than to the Island and State of Hawai‘i because of the relative sizes of the local economies. Overall, locating the Outrigger Telescopes Project would offer a moderate socioeconomic benefit to La Palma and small benefit to the Canary Islands.

4.3.11 Air Quality

A marine inversion layer occurs throughout the Canary Islands for 90 percent of the year. This inversion layer protects the ORM and high altitude portions of the caldera from any air pollution generated at lower elevations on La Palma. Generally air quality is very good at the ORM.

On-Site Construction and Installation Impacts. The analysis provided in Section 4.1.11.2 for the W.M. Keck Observatory is generally applicable to the GTC alternative, with one exception. Since the two highway routes to the GTC are entirely paved, there would be no dust generated by traffic to and from the GTC. With the implementation of the mitigation measures mentioned below, the adverse environmental impacts on air quality are expected to be small and slightly less than for the W.M. Keck Observatory site.

Operation Impacts. During operation of the Outrigger Telescopes, air quality would return virtually to the same levels as prior to construction. The only incremental impacts would be the few additional vehicle round trips to the GTC site by operational personnel. Adverse impact to air quality would be zero.

Mitigation Measures. Construction activities would comply with Spanish and Canary Island air quality requirements. In addition, the specific mitigation measures described in Section 4.1.11.2 would be implemented.

4.3.12 Noise

The GTC is sufficiently below the north rim of the caldera that it cannot be viewed from the primary tourist overlooks, which are located on the south rim.

On-Site Construction and Installation Impacts. The analysis presented in Section 4.1.12.2 for the W.M. Keck Observatory site generally applies to the GTC site with certain exceptions. There are no religious practices conducted in the vicinity. There is little recreational use in the area. The great preponderance of tourism terminates along the south rim, where noise impacts are mitigated by distance 8 km (5 mi) and noise screening due to the GTC site being located below the caldera rim. However, buses also do frequently visit the ORM primarily to provide tourists views of the observatory. Construction noise should not be incompatible with such a purpose. Noise impacts would be small and less than at Mauna Kea.

Operation Impacts. The analysis presented in Section 4.1.12.2 for the W.M. Keck Observatory equally applies to the GTC alternative. Noise impacts would be effectively zero.

Mitigation Measures. Noise mitigation measures required by the pertinent regulatory authorities would be implemented.

4.3.13 Visual/Aesthetics

The GTC is on the north side of the north rim of the caldera.

On-Site Construction, Installation, and Operations Impacts. While some tourists visit the south rim of the caldera to view the existing observatories in the ORM, there is sensitivity that these structures may adversely effect the visual view plane. Approval of the GTC project by the National Park de la Caldera de Taburiente was dependent, in large part, upon the fact that it would not be visible from the south rim visual outlooks. Similarly, the Outrigger Telescopes that are much shorter than the GTC would not be visible from the south rim. Also, being on the north side of the north rim, the Outrigger Telescopes would be shielded from view from the major population centers, which are located to the south. The ORM is not visible from north shore island communities due to the steep slopes that make up the mountainous terrain. The Outrigger Telescopes would be compatible visually with the other telescopes and observatories in the ORM. Viewing the observatories themselves is the primary purpose of tourists visiting the ORM. The adverse impact would be effectively zero.

4.4 POTENTIAL ENVIRONMENTAL CONSEQUENCES OF THE NO-ACTION ALTERNATIVE

Under the No-Action Alternative, NASA would not fund on-site construction, installation, or future operation of the Outrigger Telescopes Project proposed for the W.M. Keck Observatory site at Mauna Kea. The potential environmental impacts described for the Outrigger Telescopes Project would not occur. If the Outrigger Telescopes are not constructed and installed at the W.M. Keck Observatory on Mauna

Kea, the facilities at the W.M. Keck Observatory site would consist of the two existing 10-m (33-ft) Keck Telescopes, which are capable of functioning as the Keck-Keck Interferometer. NASA would not be able to attain the four science objectives of the Outrigger Telescopes Project discussed in Section 1.3. In addition, the No-Action Alternative would result in economic losses to the State of Hawaiʻi estimated at $13 million for the on-site construction and installation of six Outrigger Telescopes. The incremental revenues ($5 to $7 million annually) that would be associated with operation of the Outrigger Telescopes Project would also be lost to the State. NASA's funding of the Wēkiu bug on-site mitigation, the autecology study, and the Wēkiu bug monitoring activities would not occur. NASA's funding of the on- and off-site mitigation activities proposed by NASA in the NHPA Section 106 process would also not occur.

The environmental impacts attributed to the implementation of the Outrigger Telescopes Project would not occur. The impacts of past, present, and foreseeable future activities on Mauna Kea would be unchanged (see Section 4.2). Since the incremental impacts of the Outrigger Telescopes Project would be generally small, the overall cumulative impacts would generally be as described in Section 4.2.