(7) Communications

When winds exceed 100 mph (strong Typhoon Category 2 winds), microwave transmitters may be blown out of alignment, and many Cable TV lines will be blown down. When winds exceed 125 mph (strong Typhoon Category 3 winds), some HF antenna towers and weaker satellite dishes (e.g., TV) will be destroyed, and Cable TV will incur considerable downed lines. When winds exceed 160 mph (weak Typhoon Category 5 winds), there will be extensive damage to communications towers, large antennas and large satellite communications dishes. Many local telephone junction boxes will be damaged or destroyed.

(8) Highway system

For the most part, Guam highways are not excessively vulnerable to typhoon damage. Some damage can be expected when winds exceed 110 mph (weak Typhoon Category 3 winds). The new sea wall near Inarajan will protected the roads, until winds exceed 140-150 mph (medium Typhoon Category 4 winds). At these wind speeds, highways in Hagåtña, Asan, and Piti are vulnerable to some damage. Land slides may block some parts of the Agat-Umatac Highway. The biggest problem will be downed, trees, poles, and lines.

(9) Health care facilities

The Guam Memorial Hospital will incur some damage to windows and doors when winds exceed 140-150 mph (medium to strong Typhoon Category 4 winds), but the loss will escalate rapidly as winds increase. Peripheral equipment such as air conditioning units will receive significant damage or will be destroyed. The hospital should have emergency generators capable of running for long periods of time to cope with very long power outages in the event of a Typhoon Category 5 storm.

(10) Schools and shelters

(a) Guam schools are used as shelters. The individual schools need to be evaluated by a structural engineer to determine the winds they can withstand as shelters. In general, structures with wooden and tin roofs should not be used for tropical cyclones predicted to be stronger than 115 mph (weak Typhoon Category 3 winds). The selection of shelters should be based on the predicted wind speed plus 25 mph to compensate for intensity forecast errors.

(b) Schools used as shelters should have emergency generators, ample bathroom facilities, a source of drinking water, and underground telephone lines.

(11) Fuel storage facilities

With winds of 150 mph (strong Typhoon Category 4 winds), above-ground steel fuel tanks could be damaged if they are empty. Partially full tanks will be susceptible to damage when winds reach 160 mph (weak Typhoon Category 5 winds) and even full reservoirs may be damaged or destroyed when winds reach 170-180 mph (medium to strong Typhoon Category 5 winds).

(12) Sites for debris storage

Debris removal for Typhoon Paka was a very challenging problem. Had Paka's eye passed directly across the Island, the debris would have been 70-80% greater. If winds reach 160 mph (weak Typhoon Category 5 winds), debris could be 4 times the amount with Paka; at 170 mph (medium Typhoon Category winds), 8 times the amount; and, with 185 mph winds (strong Typhoon Category 5 winds), 15-16 times the amount. Damaged and destroyed vehicles would constitute a large part of the debris.

(13) Socio-Economic vulnerabilities

(a) While Guam has responded well to typhoons of intensity up through Typhoon Category 4, a Typhoon Category 5 storm will present problems not before faced by the people of Guam. If winds reach 170 mph (medium Typhoon Category 5), Guam will have to deal in the short term with death, looting, rats, snakes, and a devastated infrastructure and in the long term with unemployment, closed businesses, a reduced standard of living, and a good deal of migration from the island. Recovery to "normal" could take 5 years. If winds reach 185 mph (strong Typhoon Category 5), Guam will face unimaginable devastation and a great deal of migration could occur from the island. Recovery to "normal" could take more than 15 years.

(b) The most vulnerable sector of the population is that composed of migrants from Micronesian islands searching for work and H2 workers brought to Guam, primarily for construction jobs. A large percentage of this population lives in large groups in substandard housing and has a limited on-island family structure. A large portion of this sector will likely continue to require sheltering and supplemental assistance for nearly all typhoon events. Other vulnerable sectors are farmers, people living on untitled land, the homeless, the elderly, and the handicapped.

(c) Tourism is a very vulnerable part of the Guam economy. Any typhoon in the Typhoon Category 4 to Typhoon Category 5 range will greatly stress the tourism industry. In the Category 5 range, there will be considerable hotel and vehicle damage. The landscaping will be devastated. The airport will experience considerable damage to jet ways and considerable water damage. Recovery time will be in terms of years – about 2 years for 160 mph winds (weak Typhoon Category 5 winds), about 5 years for 170 mph winds (medium Typhoon Category winds), and more than 15 years for 185-190 mph winds (strong Typhoon Category 5 winds).

10.4. Typhoon Mitigation

Guam, in partnership with the Federal Emergency Management Agency (FEMA), has implemented a multitude of typhoon mitigation initiatives. Three of the most important have been the power pole-hardening project, projects placing tele-communications lines underground, and the water well emergency generator project. Many smaller projects have been implemented as well. FEMA and others have prepared well-written documents that address structural wind damage and present mitigation measures that can be taken to improve wind damage resistance of structures and segments of the infrastructure. Some of these are summarized in Table 10.5.

Table 10.5. Summary of publications that address structural damage and that present mitigation measures for improving structures and infrastructure. BTMTD: means "Building to Minimize Typhoon Damage:" (Refer to References section).

Publication	Agency
Building Performance: Hurricane Iniki in Hawaii (1993)	FEMA
Typhoon Paka: Observations and Recommendations on Building Performance and Electrical Power Distribution System, Guam, U.S.A. (1998)	FEMA
BTMTD: Guidelines for Guam Department of Public Works Plan Reviewers and Inspectors (1998)	FEMA
BTMTD: Design Guidelines for Essential Facilities (1998)	FEMA
BTMTD: In-Residence Shelter Design (1998)	FEMA
BTMTD: Design Guidelines for Buildings (1998)	FEMA
BTMTD: Anchoring Shipping Containers (1998)	FEMA
Manual for the Evaluation of Buildings in High Wind Regions (undated)	SBCCI

11. POPULATION BEHAVIOR ANALYSIS

Guam is an isolated island that experiences a relatively large number of typhoon threats. As such, its population responds differently and for different reasons than do the populations of other hurricane-prone US areas. In the Southeast US, a large percent of the population has never experienced a severe hurricane. As a result, they have no experience with, or concept of, the destructive forces of the hurricane winds or storm surge (Jarrell et al. 1992). Evacuation responses are the biggest concern there. Hawaii, especially Oahu and Maui counties, has a similar problem in that the occurrence of destructive hurricanes is rare. A Behavioral Analysis, largely based on a limited survey, for Leeward Oahu (HMG 1995) found that many residents did not realize that evacuation notices given through the media applied to them. There was also the perception that the storm surge was a much greater threat than the wind. The study also revealed that low income people were more apt to evacuate and to use shelters.

On Guam, the population behavior is fairly predictable, not always prudent, but predictable. On Guam, the village mayors and the police are very active in the warning and evacuation processes. Mayors do not rely solely on the media or on even on the Guam Emergency Management Office to motivate people at risk to leave. Despite the frequent experiences of Guam's population with typhoons, there are certain shortfalls in response. These shortfalls and the reasons for them are discussed below.

11.1. RESPONSE TO WARNINGS

Guam has gone through numerous typhoons without a fatality. This suggests that the warning process is relatively flawless and certainly effective when it comes to preventing loss of life. However, during every typhoon, there are many rescues that should not have been necessary. The reasons for the lack of timely action on the part of those requiring rescue can be narrowed down to four major factors.

(1) Lack of understanding of the warnings or confusion about the warnings;

(2) Questionable confidence in the warnings;

(3) Overestimating the ability of the structure to endure the wind; and,

(4) Reluctance to leave the comfort of ones home.

While Guam Fire Department and the Guam Police Department personnel are excellent at rescuing those who require it, the lives and safety of the rescuers are often put at risk. This is especially true when the wind intensity reaches or exceeds Typhoon Category 3. At these wind speeds, flying debris can cause fatalities. Emergency vehicles, such as police cars, rescue vehicles, and ambulances, can be blown off of highways when wind intensities reach Typhoon Category 4 or stronger. **In general, rescue workers should**

not leave their shelters once sustained winds reach 115 mph. It is often difficult to determine when and where the winds reach this intensity, and thus **it is important to have a network of survivable wind measuring equipment around the island with readout capability at the Office of Emergency Management.** While the Doppler radar can provide some of this information, it does not measure the wind at the surface, and it is subject to failure at the height of the typhoon when the information is most critical.

11.2. MISUNDERSTANDING AND CONFUSION ASSOCIATED WITH WARNING INFORMATION

There are two aspects of a tropical cyclone warning that cause confusion and misunderstanding:

(1) One is the lack of understanding on what the numerical wind values mean in terms of damage to their property.

(2) The other is confusion arising from the different warning levels designed to trigger preparedness actions. Confusion also occurs because the civilian and the military communities may be in different warning levels.

11.2.1. Lack of Understanding of Numerical Wind Values

Few of the general public understand the relationship between a given typhoon intensity (numerical value) and the potential damage that it can cause. Worse still, many disaster officials are forced to make decisions without a clear understanding of the damage a specific wind can produce. This is a major reason for the development of the Saffir-Simpson Hurricane Scale, which places hurricanes into five distinct intensity categories and describes the potential damage expected by the winds in each category. This Scale has only been validated in the Atlantic. Guard and Lander have made several modifications to the Atlantic scale and have adapted it for use in the tropical Pacific. **This Scale, coined the Saffir-Simpson Tropical Cyclone Scale (STCS – pronounced "sticks"), has been tested extensively on Guam and in other tropical regions, and should be adapted by the Guam Office of Emergency Management as soon as possible.** A public information program will be needed to introduce the Scale to the media and general public. This Scale will alleviate much of the confusion experienced when numerical wind values are given.

11.2.2. Confusion Associated with Warning Criteria

Guam has a relatively complex set of warning criteria. This has developed because of the differing needs of the military and civilian communities. For warning purposes, Guam employs the military nomenclature of Conditions of Readiness (COR). While the military uses a single set of CORs, Tropical Cyclone Conditions of Readiness, Guam uses two sets of CORs, Tropical Storm COR and Typhoon COR. These are defined as follows:

<u>Tropical Storm Conditions of Readiness</u> -- The maximum intensity of the tropical cyclone when it is closest to Guam is expected to be less than 74 mph (63 kt); i.e., tropical storm intensity.

<u>Tropical Storm COR 4</u> -- Winds of **60 mph** (50 kt) or greater are ***possible*** within **72 hr**

<u>Tropical Storm COR 3</u> -- Winds of **60 mph** (50 kt) or greater are ***possible*** within **48 hr**

<u>Tropical Storm COR 2</u> -- Winds of **60 mph** (50 kt) or greater are ***anticipated*** within **24 hr**

<u>Tropical Storm COR 1</u> -- Winds of **60 mph** (50 kt) or greater are ***anticipated*** within **12 hr** or are already occurring.

<u>Typhoon Conditions of Readiness</u> -- The maximum intensity of the tropical cyclone when it is closest to Guam is expected to be greater than or equal to 74 mph (63 kt); i.e., typhoon intensity.

<u>Typhoon COR 4</u> -- Winds of **60 mph** (50 kt) or greater are ***possible*** within **72 hr**

<u>Typhoon COR 3</u> -- Winds of **60 mph** (50 kt) or greater are ***possible*** within **48 hr**

<u>Typhoon COR 2</u> -- Winds of **60 mph** (50 kt) or greater are ***anticipated*** within **24 hr**

<u>Typhoon COR 1</u> -- Winds of **60 mph** (50 kt) or greater are ***anticipated*** within **12 hr** or are already occurring.

The Tropical Storm CORs are implemented when there is some uncertainty that Guam will experience typhoon-force winds. This gives the Governor some flexibility in releasing government workers and closing schools. When <u>Typhoon</u> COR 2 is declared, by law the Governor must release non-essential government personnel. But, the dual -- Typhoon and Tropical Storm -- nomenclature is confusing to a large segment of the population. And, the fact that the military is often in a different COR than the civilian community is another source of confusion.

To add even more confusion to the process, the National Weather Service (NWS) employs a *watch-warning* nomenclature that is commonly used in the mainland US. A *tropical storm watch* is issued when a tropical storm is expected to affect the area within 48 hours, and a *tropical storm warning* is issued when a tropical storm is expected to affect the island within 24 hours. *Typhoon watch* and *typhoon warning* have the same time criteria for typhoons Because the NWS nomenclature and timelines are different from the CORs, another level of confusion is added to the warning process.

Guam should seriously consider moving to the *watch-warning* nomenclature of the National Weather Service and let the military use the COR nomenclature for their local facility preparedness.

11.2.3. Lack of Confidence in Warnings

Guam experiences considerably more near misses from tropical cyclones than direct hits. Slightly more than half of the near misses pass south of the island, subjecting the island to the strong or dangerous semi-circle of winds. Because of this and the relative large numbers of weaker structures in the south, these near misses to the south cause considerable damage in the south, but often spare the stronger structures in the north. Near misses to the north cause significantly less damage, because the weaker sector of the typhoon is hitting the island and the structures in the north are, in general, stronger.

Frequently, there is a gap between direct hits with many near misses occurring between the direct hits. During this gap, several of the near misses are predicted to be direct hits. These repeated "false alarms" (despite the fact that warnings may be fairly accurate) often lead the public to attempt to out-guess the warning agency by assuming another near miss. In this case, shutters may be put up on only one side of the house. If the direct hit occurs, so does water and debris damage on unprotected areas of the structure.

There is also a misconception of the behavior of the winds associated with an eye passage. Some of the population believe that a typhoon's winds come from one direction, a belief that comes from their experiences from near misses to the south. Thus, when an eye passage occurs and the winds change from one direction to the opposite direction, some people think that the typhoon reversed its motion and hit the island a second time. This is perceived to be a foul-up by the warning agency.

There is an expectance for every warning to be perfectly accurate. **Preparation in response to typhoon warnings should be looked at in the manner of obtaining insurance.** You prepare for the worst and hope for the best. People buy fire insurance and automobile insurance, but they don't complain at the end of the year if the house didn't burn down or they didn't total the car.

Preparing for a typhoon takes some time and money. This expenditure is part of the price we pay to live on this beautiful island. It is no different than an annual allocation in Minneapolis for snow removal. **People must get in the mind-set of budgeting some annual expenditure for typhoon preparations.**

11.2.3. Over-Estimating the Strength of Structures

Many people over-estimate the ability of their structure to withstand the predicted winds. This occurs in part from the inability to relate an advertised numerical wind intensity to its potential destructive capability (see paragraph 8.2.1.). However, there are also some common misconceptions about structures. Just because a structure survived a typhoon 20 years ago, does not mean that it will survive a similar typhoon now. This is especially true with wooden and metal structures which can deteriorate considerably over time.

While a wooden structure can be built to withstand weak Typhoon Category 4 winds, it will likely not hold up to Typhoon Category 3 winds in 25-30 years, at least not without very conscientious maintenance of roofs, windows, and doors. The same is true for sheet metal structures. Repeated exposure to salt air, hot sun, and strong winds causes gaps to develop where the sheets of metal are joined and where the roof is joined to the walls. This eventually allows wind to get under the sheet metal and rip it from the supporting steel skeleton.

11.2.4. Reluctance to Leave the Comfort of One's Home

There is a reluctance to leave the comfort of ones home. No one wants to give up the privacy and comfort of home to go to a shelter and share close quarters with a crowd of people, many times strangers. There is also a reluctance to leave ones valuables and belongings behind. These factors then combine with (1), (2), and (3) above to give a person a false feeling of security. They may have survived many weaker storms and cannot envision the significance of additional wind of 20-25 mph. They may have survived the peripheral winds of stronger typhoons and have the false impression that they survived the full brunt of a "super" typhoon. They may have experienced several warnings that were false alarms and have the idea that they can out-forecast the experts.

These people often have to be rescued, and usually at the height of the typhoon. This not only puts them in harm's way, but it puts the rescuers in harm's way. And it puts the rescue equipment in harm's way.

11.3. RECOMMENDATIONS

The Guam Mayor's Council is well aware of these problems. The members are satisfied with the recommendations outlined in two documents: (1) Results and Recommendations determined at the Paka Lessons Learned Workshop, March 16-18, 1998, Hilton Hotel, Tumon, Guam (GOVGUAM 1998b) and in the (2) Hazard Mitigation Survey Team Report, Typhoon Paka, FEMA DR-1193-GU (GOVGUAM, 1998a). It is the view of the Council that implementation of the pertinent recommendations in these documents will go a long way in mitigating the behavioral problems (Frank Camacho, personnel communication). Therefore, we recommend that the recommendations of Paka Lessons Learned Attachment 1 (Improve the flow of information to the public and within

GOVGUAM before, during, and after disaster) and the recommendations of the Hazard Mitigation Survey Team Report Item 9 (Reduce public confusion due to Emergency Terminology) be implemented.

REFERENCES

ADB, (Undated, circa 1992): Disaster Mitigation in Asia and the Pacific. Asian Development Bank, Manila, Republic of the Philippines, 392 pp.

Atkinson, G. D., and C. R. Holliday, 1977: Tropical Cyclone minimum sea level pressure/maximum sustained wind relationship for the western North Pacific. *Mon. Wea. Rev.*, **105**, 421-427.

Callaghan, J., and R. K. Smith, 1998: The relationship between maximum surface wind speeds and central pressure in tropical cyclones. *Australia Meteorological Mag.*, 47, 191-202.

Central Meteoroogical Bureau, 1983: Northwest Pacific Typhoon Track Maps, 1949-1980, 576 pp. (People's Republic of China)

Curtis, D. C., 1995: Wind Effects on Rain Gauge Catch. Alert Transmission, Summer 1995, pp. 6-7.

Dvorak, V. F., 1977: Tropical cyclone intensity analysis and forecasting from satellite imagery. *Mon. Wea Rev.*, **103**, 420-430.

Dvorak, V. F., 1984: Tropical cyclone intensity analysis using satellite data. NOAA Technical Report NESDIS 11, US Department of Commerce, Washington, DC, 47 pp.

FEMA, 1993: Building Performance: Hurricane Iniki in Hawaii -- Observations, Recommendations, and Technical Guidance. Federal Emergency Management Agency and Federal Insurance Administration, 100 pp.

FEMA, 1997: Debris Management Course, Emergency Management Institute, Student Manual 202. National Emergency Training Center, Federal Emergency Management Agency, (Multiple Units).

FEMA, 1998a: Building to Minimize Typhoon Damage: Anchoring Shipping Containers, Federal Emergency Management Agency Region IX and the Government of Guam, 4 pp.

FEMA, 1998b: Building to Minimize Typhoon Damage: Design Guidelines for Buildings, Federal Emergency Management Agency Region IX and the Government of Guam, 38 pp.

FEMA, 1998c: Building to Minimize Typhoon Damage: Design Guidelines for Essential Facilities, Federal Emergency Management Agency Region IX and the Government of Guam, 8 pp.

FEMA, 1998d: Building to Minimize Typhoon Damage: Guidelines for Guam Department of Public Works Plan Reviewers and Inspectors, Federal Emergency Management Agency Region IX and the Government of Guam, 8 pp.

FEMA, 1998e: Building to Minimize Typhoon Damage: In-Residence Shelter Design, Federal Emergency Management Agency Region IX and the Government of Guam, 7 pp.

FEMA, 1998f: Building to Minimize Typhoon Damage: Inspecting, Maintaining, and Repairing Buildings, Federal Emergency Management Agency Region IX and the Government of Guam, 6 pp.

FEMA, 1998g: Typhoon: Observations and Recommendations on Building Performance and Electrical Power Distribution System, Guam, USA--Final Report. FEMA-1193-DR-GU, Federal Emergency Management Agency Region IX and Government of Guam, 104 pp (12 Chapters).

GOVGUAM, 1998a: Hazard Mitigation Survey Team Report, Typhoon Paka. FEMA DR-1193-GU. Government of Guam and the Federal Emergency Management Agency, 38 pp

GOVGUAM, 1998b: Results and Recommendations, Paka Lessons Learned Workshop March 16-18. 1998, Tumon, Guam, 41 pp.

GOVGUAM, 1998c: Annual Census of Establishments: March 1998 Guam, Bureau of Labor Statistics, Department of Labor, Government of Guam, 59 pp.

GOVGUAM, 1998d: Final I Tano'-ta Land Use Plan, Exhibit 1, Government of Guam, Hagåtña, Guam, 189 pp

GOVGUAM, 1998e. Final I Tano'-ta Land Use Plan, Exhibit 2, Government of Guam, Hagåtña, Guam, 335 pp

Guard, C. P., 1995: Hurricane (Typhoon) Program Needs Assessment. Prepared for the Guam Emergency Management Office and the Federal Emergency Management Agency, 120 pp.

Guard, C. P., and M. A. Lander, 1999: A Tropical Cyclone Wind-Damage Scale for the Tropical Pacific. WERI Technical Report 86, Water and Environmental Research Institute of the western Pacific, University of Guam, Mangilao, Guam, (in print).

Gutierrez, C. T. C., M. Z. Bordallo, J. C. Cruz, E. I. Cruz, and E. Y. Li., 1998: Guam Annual Economic Review 1998-1997. Economic Research Center, Department of Commerce, Tiyan, Guam, 58 pp. + Appendix.

HMG, 1995: Leeward Oahu Hurricane Vulnerability Study Behavioral Analysis, Prepared for State of Hawaii and US Army Corps of Engineers, Hazards Management Group, Inc. Tallahassee, FL, 31 pp

Jelesnianski, C. P., J. Chen, and W. A. Shaffer, 1992 SLOSH: Sea, Lake, and Overland Surges from Hurricanes, NOAA Technical Report NWS 48, Department of Commerce, Washington, DC, 71 pp.

Jarrell, J. D., P. J. Hebert, and M. Mayfield, 1992: Hurricane Experience Levels of Coastal County Populations from Texas to Maine. NOAA Technical Memorandum NWS NHC-46, National Oceanic and Atmospheric Administration, Department of Commerce, Washington, DC, 152 pp.

JTWC, 1980-1996: Annual Tropical Cyclone Report. US Naval Pacific Meteorological and Oceanography Center West/Joint Typhoon Warning Center Guam, FPO AP 96536-0051.

JTWC, 1962-1979: Annual Typhoon Report. US Naval Pacific Meteorological and Oceanography Center West/Joint Typhoon Warning Center Guam, FPO AP 96536-0051.

JTWC: Tropical Cyclones Affecting Guam --1671-1990. NOCC/JTWC Tech Note 91-2, US Naval Pacific Meteorological and Oceanography Center West/Joint Typhoon Warning Center Guam, FPO AP 96536-0051, 45 pp.

Krayer, W. R. and R. D. Marshall, 1992: Gust Factors Applied to Hurricane Winds. *Bulletin of the American Meteorological Society*, **120**, pp. 613-617.

Lander, M. A. and C. P. Guard, 1997: High Wave Events: NAVSTA Family Housing Project, Prepared for Moffatt & Nichol Engineers, Long Beach CA, 66 pp

MRC, 1990: Windstorm--New Loss Dimensions of a Natural Hazard, Munich Reinsurance Company, Munich, Germany, 116 pp.

Neumann, C. J., 1987 (reprinted with corrections, 1991): The National Hurricane Center Risk Analysis Program (HURISK). NOAA Technical Memorandum, NWS NHC 38, 56 pp.

PAG, 1998: 3 March 1998 Memo, Subject: Supertyphoon Paka Supplemental Funding. Port Authority of Guam, 7 pp.

*PDN, 1999: "Port calls crane contract 'bad'", January 20, 1999, p.49.

Phillips, B. (editor), 1998: Estorian Paka: Guam's Spirit of Recovery--Super Typhoon Paka, December 16-17, 1997, Governor and Lt. Governor of Guam, 59 pp.

Pielke, R. A. Jr., 1995: Hurricane Andrew in South Florida: Mesoscale Weather and Societal Responses. National Center for Atmospheric Research, Boulder, CO, 212 pp.

Pielke, R. A., Jr., and C. W. Landsea, 1998: Normalized hurricane damages in the United States: 1925-95. *Weather and Forecasting*, **13**, 621-631.

Pielke R. A. Jr., and R. A. Pielke, Sr., 1995: Hurricanes: Their Nature and Impacts on Society. John Wiley, 279 pp.

Randall, R. H., and L. G. Eldredge, 1976: Atlas of the reefs and beaches of Guam. Bureau of Planning, Government of Guam, Agana, Guam, 100 pp.

Rupp, J. A., and M. A. Lander, 1996: A technique for estimating recurrence intervals of tropical cyclone-related high winds in the tropics: Results for Guam. *Journ. Applied Science*, **35**, 628-637.

SBCCI, (undated): Manual for the Evaluation of Building Located in High Wind Regions, Southern Building Code Congress, Inc. Birmingham, AL, 73 pp.

SEI, 1993: Leeward Oahu Hurricane Vulnerability Study: Determination of Coastal Inundation Limits, Prepared for State of Hawaii, US Army Corps of Engineers, and FEMA, Sea Engineering, Inc., Makai Research Pier, Waimanalo, Hawaii, multiple annexes.

Siegrist, H. G. Jr, 1998: Seismic Hazard Vulnerability on Guam: A Summary. WERI Technical Report No. 77, University of Guam, 46 pp.

Simpson, R. H., 1974: The hurricane disaster potential scale. *Weatherwise*, **27**, 169 and 186.

USACE, 1980: Guam Comprehensive Study Shoreline Inventory. US Army Corps of Engineers and Sea Engineering Services, Inc., Honolulu, HI, (10 Sections).

USACE, 1985: Hurricane Vulnerability Study for Honolulu, Hawaii, and Vicinity, Volume 1, Hazard Analysis, Prepared for State of Hawaii Department of Defense, US Army Corps of Engineers Pacific Ocean Division, Ft. Shafter, HI, 51 pp.

USACE, 1991: Commercial Port Road, Cabras Island, Guam, Coastal Flooding Study, Section 205, Reconnaissance Report. US Army Corps of Engineers, Honolulu, Hawaii, 7 pp.

USACE, 1994a: Leeward Oahu Hurricane Vulnerability Study, Enumeration of Population, Dwelling Structures, Critical Facilities, and Lifelines, Prepared for State of Hawaii, Department of Defense, US Army Corps of Engineers Pacific Ocean Division and FEMA Region IX, 9 pp (+ Multiple Annexes).

USACE, 1994b: Leeward Oahu Hurricane Vulnerability Study, Impact of Hurricane Strength Wind on Typical Dwelling Structures on Leeward Oahu (Waianae & Wahiawa Districts), Prepared for State of Hawaii, Department of Defense, US Army Corps of Engineers Pacific Ocean Division and FEMA Region IX. (Multiple Appendices)

USACE, 1992. Plan of Study, Leeward Oahu Hurricane Vulnerability Study, State of Hawaii, US Army Corps of Engineers Pacific Ocean Division, Ft. Shafter, HI, 9 pp.

USACE, 1995a: Leeward Oahu Hurricane Vulnerability Study, Transportation Analysis, Prepared for State of Hawaii, Department of Defense, US Army Corps of Engineers Pacific Ocean Division and FEMA Region IX, Ft. Shafter, HI, 21 pp.

USACE, 1995b: Leeward Oahu Hurricane Vulnerability Study, Transportation Analysis Model Support Document, Prepared for State of Hawaii, Department of Defense, US Army Corps of Engineers Pacific Ocean Division and FEMA Region IX, Ft. Shafter, HI, 24 pp + Appendices.

APPENDICES

APPENDIX A

NAMES FOR TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC OCEAN AND SOUTH CHINA SEA

Column 1		Column 2		Column 3		Column 4	
ANN	*AN*	**ABEL**	*A-bel*	**AMBER**	*AM-ber*	**ALEX**	*AL-x*
BART	*BART*	**BETH**	*BETH*	**BING**	*BING*	**BABS**	*BABS*
CAM	*KAM*	**CARLO**	*KAR-lo*	**CASS**	*KASS*	**CHIP**	*CHIP*
DAN	*DAN*	**DALE**	*DAY-l*	**DAVID**	*DAY-vid*	**DAWN**	*DAWN*
EVE	*EEV*	**ERNIE**	*ER nee*	**ELLA**	*EL-la*	**ELVIS**	*EL vis*
FRANKIE	*FRANK-ee*	**FERN**	*FERN*	**FRITZ**	*FRITZ*	**FAITH**	*FAITH*
GLORIA	*GLOR-ee-uh*	**GREG**	*GREG*	**GINGER**	*JIN-jer*	**GIL**	*GIL*
HERB	*HERB*	**HANNAH**	*HAN-nah*	**HANK**	*HANGK*	**HILDA**	*HIL-dah*
IAN	*EE-an*	**ISA**	*EE-sah*	**IVAN**	*I- van*	**IRIS**	*I-ris*
JOY	*JOY*	**JIMMY**	*JIM ee*	**JOAN**	*JONE*	**JACOB**	*JAY-kob*
KIRK	*KIRK*	**KELLY**	*KEL-lee*	**KEITH**	*KEETH*	**KATE**	*KATE*
LISA	*LEE-sah*	**LEVI**	*LEEV-eye*	**LINDA**	*LIN-dah*	**LEO**	*LEE-o*
MARTY	*MAR-tee*	**MARIE**	*mah REE*	**MORT**	*MORT*	**MAGGIE**	*MAG-gee*
NIKI	*NI-kee*	**NESTOR**	*NES tor*	**NICHOLE**	*nik-KOL*	**NEIL**	*NEEL*
ORSON	*OR-son*	**OPAL**	*O-pel*	**OTTO**	*OT-tow*	**OLGA**	*OL-gah*
PIPER	*PI per*	**PETER**	*PEE-ter*	**PENNY**	*PEN-nee*	**PAUL**	*PAUL*
RICK	*RICK*	**ROSIE**	*RO-zee*	**REX**	*REX*	**RACHEL**	*RAY-chel*
SALLY	*SAL-lee*	**SCOTT**	*SKOT*	**STELLA**	*STEL-lah*	**SAM**	*SAM*
TOM	*TOM*	**TINA**	*TEE-nah*	**TODD**	*TOD*	**TANYA**	*TAHN-yah*
VIOLET	*VI ith-let*	**VICTOR**	*vik-TOR*	**VICKI**	*VIK-kee*	**VIRGIL**	*VER-jil*
WILLIE	*WIL lee*	**WINNIE**	*WIN nee*	**WALDO**	*WAL-do*	**WENDY**	*WEN-dee*
YATES	*YATES*	**YULE**	*YOU-l*	**YANNI**	*YAN-ni*	**YORK**	*YORK*
ZANE	*ZANE*	**ZITA**	*ZEE-tah*	**ZEB**	*ZEB*	**ZIA**	*ZEE-uh*

NOTE 1: Assign names in rotation, alphabetically, starting with (ANN) for first tropical cyclone of 1996. When the last name in Column 4 (ZIA) has been used, the sequence will begin again with the first name in Column 1 (ANN).

NOTE 2: Pronunciation guide for names is italicized.

SOURCE: 1996 Annual Tropical Cyclone Report, Joint Typhoon Warning Center

APPENDIX B

MAXIMUM SUSTAINED SURFACE WINDS AND EQUIVALENT MINIMUM SEA-LEVEL PRESSURE

WIND SPEED (knots)	WIND SPEED (mph)	MINIMUM PRESSURE (millibars)	MINIMUM PRESSURE (inches of mercury)[1]
30	35	1000	29.53
35	40	997	29.44
40	46	994	29.35
45	52	991	29.26
50	58	987	29.14
55	63	984	29.06
60	69	980	28.94
65	75	976	28.82
70	80	972	28.64
75	86	967	28.55
80	92	963	28.44
85	98	958	28.29
90	104	954	28.17
95	109	948	27.99
100	115	943	27.85
105	121	938	27.70
110	127	933	27.55
115	132	927	27.37
120	138	922	27.23
125	144	916	27.05
130	150	910	26.87
135	155	906	26.75
140	161	898	26.52
145	167	892	26.34
150	173	885	26.13
155	178	879	25.96
160	184	872	25.75
165	190	865	25.54
170	196	858	25.34
175	201	851	25.13

[1] **Based on Atkinson-Holliday wind-pressure relationship (Atkinson and Holliday 1977).**

APPENDIX C

THE SAFFIR-SIMPSON TROPICAL CYCLONE SCALE FOR THE TROPICAL PACIFIC

Adapted from the Saffir-Simpson Hurricane Scale Used in the Atlantic Basin

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1. GENERAL COMMENTS

The Saffir-Simpson Tropical Cyclone Scale (STCS -- pronounced "sticks") has two purposes. First, it is developed to give decision makers and the general public an idea of the level of damage to expect from an advertised numerical tropical cyclone intensity value. This should alleviate much of the confusion that exists when lay people are confronted with numerical intensity values. Second, it can be used in analysis and post-analysis by a trained observer to assess the intensity of a tropical cyclone when wind-measuring instruments are not available, have malfunctioned, or have been destroyed.

The following paragraphs describe the two tropical storm categories and the five typhoon/hurricane categories of the Saffir-Simpson Tropical Cyclone Scale, and the ranges of wind that pertain to each. The categories herein are based on a 1-minute average maximum sustained wind (MSW) and a 1-3 second peak gust. These values are given in miles per hour (mph) and knots (kt). The common names of the vegetation types described in STCS are for Guam, the Commonwealth of the Northern Mariana Islands, and much of Micronesia. The scientific names (*Genus species*) are shown in the text. If there are multiple species, the species name is replaced with *spp.* While the species names are useful, it is the Genus that most closely delineates the plant's response to the wind. In adapting STCS for a specific locale, the vegetation types should be converted to the more common plant names that pertain to the given Genus and local species, since plant species often vary from region to region. Structures and infrastructure described herein are those commonly found in tropical and subtropical regions. Common building techniques and practices used in tropical regions are also factored into the Scale. The structure types span the spectrum from small poorly constructed lean-to type structures to massive steel reinforced concrete structures. The weakening effects of termites, wood rot, and salt water corrosion are addressed where appropriate. Coastal wave action/coastal inundation refer to effects in open bays fed by rivers, in harbors, and at coastlines surrounded by fringing reefs. These values are given in feet (ft) and meters (m), and are independent of tidal variation. Tidal variation should be factored into values to determine actual water levels. Values inside barrier reefs will be somewhat higher, depending on the distance from the reef front to the dry land and the depth of water inside the reef. For wave heights across reefs, the value represents an average value over a 250-500 foot (76-152 meter) wide reef. For narrower reefs, waves will likely be somewhat higher, and for wider reefs, waves will likely be somewhat smaller. Waves affecting sheer cliff lines are not specifically addressed in the Scale. However, as the waves hit the base of the cliff, they are similar in height to the wave and swell heights in the open ocean. When the waves crash against the cliff, large volumes of water will be forced up the face of the cliff and may reach heights more than twice the height of the incoming waves. Sheets of sea spray can reach heights more than four times the height of the incoming waves. Minimum sea level pressures are not used in the Scale due to the large variability observed in the relationship between maximum sustained wind and minimum sea level pressure in Pacific tropical cyclones. This Scale has not been tested in other tropical basins; however, in constructing the Scale, a large volume of wind and damage information from other tropical basins was assessed, and the wind-damage relationships were found to be very consistent with those observed in the Pacific. In fact, data from other tropical basins were ultimately incorporated into the development of the final Scale.

2. THE SAFFIR-SIMPSON TROPICAL CYCLONE SCALE (STCS)

a. TROPICAL DEPRESSION AND TROPICAL STORM CATEGORIES:

1) TROPICAL STORM CATEGORY A: WEAK TROPICAL STORM
MSW: 30-49 mph (26-43 kt)
Peak Gusts: 40-64 mph (33-56 kt)

Potential Damage - Damage done to only the flimsiest lean-to type structures. Unsecured light signs blown down. Minor damage to banana trees [*Musa spp.*] and near-coastal agriculture, primarily from salt spray. Some small dead limbs, ripe coconuts, and dead palm fronds blown from trees. Some fragile and tender green leaves blown from trees such as papaya [*Carica papaya*] and fleshy broad leaf plants

Coastal Inundation and Wave Action - On windward coasts, sea level rise of less than 2 ft (0.6 m) above normal in open bays and inlets due to storm surge and wind-driven waves; breaking waves inside bays can reach 2-3 ft (0.6-0.9 m); water is less than 1 ft (0.3 m) over reefs. Rough surf at reef margin with moderately strong along-shore currents (rip tides) inside reefs.

2) TROPICAL STORM CATEGORY B: SEVERE TROPICAL STORM
MSW: 50-73 mph (44-63 kt)
Peak Gusts: 65-94 mph (57-81 kt)

Potential Damage - Minor damage to buildings of light material, major damage to huts made of thatch or loosely attached corrugated sheet metal or plywood. Unattached corrugated sheet metal and plywood may become airborne. Wooden signs not supported with guy wires are blown down. Moderate damage to banana trees [*Musa spp.*], papaya trees [*Carica papaya*], and most fleshy crops. Large dead limbs, ripe coconuts, many dead palm fronds, some green leaves, and small branches are blown from trees

Coastal Inundation and Wave Action - On windward coasts, sea level rise of 2-4 ft (0.6-1.2 m) above normal in open bays and inlets due to storm surge and wind-driven waves, breaking waves inside bays can reach 3-5 ft (0.9-1.5 m); water is about 1-2 ft (0.3-0.6 m) above normal across reef flats. Wind-driven waves can inundate low-lying coastal areas below 1-2 ft (0.3-0.6 m) on windward locations where reefs are narrow. Very rough surf at reef margin with strong along-shore currents (rip tides) inside reefs.

b. TYPHOON AND SUPER TYPHOON CATEGORIES.

1) TYPHOON CATEGORY 1: MINIMAL TYPHOON
MSW: 74-95 mph (64-82 kt)
Peak Gusts: 95-120 mph (82-105 kt)

Potential Damage - Corrugated metal and plywood stripped from poorly constructed or termite-infested structures and may become airborne. A few wooden, non-reinforced power poles tilted, and some rotten power poles broken. Some damage to poorly constructed, loosely attached signs. Major damage to banana trees [*Musa spp.*], papaya trees [*Carica papaya*], and fleshy crops. Some young trees downed when the ground is saturated. Some palm fronds crimped and bent back through the crown of coconut palms [*Cocos nucifera*]; a few palm fronds torn from the crowns of most types of palm trees; many ripe coconuts blown from coconut palms. Less than 10% defoliation of shrubbery and trees; up to 10% defoliation of tangantangan [*Leucaena spp.*]. Some small tree limbs downed, especially from large bushy and frail trees such as mango [*Mangifera spp.*], African tulip [*Spathodea campanulata*], poinciana [*Delonix regia*], etc. Overall damage can be classified as minimal.

Coastal Inundation and Wave Action - On windward coasts, sea level rise of 4-6 ft (1.2-1.8 m) above normal in open bays and inlets due to storm surge and wind-driven waves; breaking waves inside bays can reach 5-7 ft (1.5-2.1 m) above normal; water is about 2-3 ft (0.6-1.0 m) above normal across reef flats. Wind-driven waves may inundate low-lying coastal roads below 2-4 ft (0.6-1.2 m) on windward locations where reefs are narrow. Minor pier damage. Some small craft in exposed anchorages break moorings.

2) TYPHOON CATEGORY 2: MODERATE TYPHOON
MSW: 96-110 mph (83-95 kt)
Peak Gusts: 121-139 mph (106-121 kt)

Potential Damage - Several rotten wooden power poles snapped and many non-reinforced wooden power poles tilted. Some secondary power lines downed. Damage to wooden and tin roofs, and doors and windows of termite-infested or rotted wooden structures, but no major damage to well-constructed wooden, sheet metal, or concrete buildings. Considerable damage to structures made of light materials. Major damage to poorly constructed, attached signs. Exposed banana trees [*Musa spp.*] and papaya trees [*Carica papaya*] totally destroyed; 10-20% defoliation of trees and shrubbery; up to 30% defoliation of tangantangan [*Leucaena spp*]. Light damage to sugar cane [*Saccharum spp.*] and bamboo [*Bambusa spp.*]. Many palm fronds crimped and bent through the crown of coconut palms [*Cocos nucifera*] and several green fronds ripped from palm trees. Some green coconuts blown from trees. Some trees blown down, especially shallow rooted ones such as acacia [*Acacia spp.*], mango [*Mangifera indica*] and breadfruit [*Artocarpus spp.*] when the ground becomes saturated. Overall damage can be classified as moderate.

Coastal Inundation and Wave Action - On windward coasts, sea level rise of 6-8 ft (1.8-2.4 m) above normal in open bays and inlets due to storm surge and wind-driven waves; breaking waves inside bays can reach 7-10 ft (2.1-3.0 m) above normal; water is about 3-5 ft (0.9-1.5 m) above normal across reef flats. Wind-driven waves will inundate low-lying coastal roads below 4-6 ft (1.2-1.8 m) on windward locations where reefs are narrow. Some erosion of beach areas, some moderate pier damage, and some large boats torn from moorings.

3) TYPHOON CATEGORY 3: STRONG TYPHOON
MSW: 111-130 mph (96-113 kt)
Peak Gusts: 140-165 mph (122-144 kt)

Potential damage - . A few non-reinforced hollow-spun concrete power poles broken or tilted and many non-reinforced wooden power poles broken or blown down; many secondary power lines downed. Practically all poorly constructed signs blown down and some stand-alone steel-framed signs bent over. Some roof, window, and door damage to well-built, wooden and metal residences and utility buildings. Extensive damage to wooden structures weakened by termite infestation, wet-and-dry wood rot, and corroded roof straps (hurricane clips). Non-reinforced cinderblock walls blown down. Many mobile homes and buildings made of light materials destroyed. Some glass failure due to flying debris, but only minimal glass failure due to pressure forces associated with extreme gusts. Some unsecured construction cranes blown down. Air is full of light projectiles and debris. Major damage to shrubbery and trees; up to 50% of palm fronds bent or blown off; numerous ripe and many green coconuts blown off coconut palms; crowns blown from a few palm trees. Moderate damage to sugar cane [*Saccharum spp.*] and bamboo [*Bambusa spp.*]. Some large trees (palm trees, breadfruit [*Artocarpus spp.*], monkeypod [*Samanea saman*], mango [*Mangifera indica*], acacia [*Acacia spp.*] and Australian pines [*Casuarina spp.*]) blown down when the ground becomes saturated; 30-50% defoliation of most trees and shrubs; up to 70% defoliation of tangantangan [*Leucaena spp.*]. Some very exposed panax [*Polyscias spp.*], tangantangan [*Leucaena spp.*], and oleander [*Nerium oleander*] bent over. Overall damage can be classified as extensive.

Coastal Inundation and Wave Action - On windward coasts, sea level rise of 8-12 ft (2.4-3.7 m) above normal in open bays and inlets due to storm surge and wind-driven waves; breaking waves inside bays can reach 10-15 ft (3.0-4.6 m) above normal; water is about 5-8 ft (1.5-2.4 m) above normal across reef flats. Wind-driven waves will inundate low-lying coastal roads below 6-10 ft (1.8-3.0 m) of elevation on windward locations where reefs are narrow. Considerable beach erosion. Many large boats and some large ships torn from moorings.

4) TYPHOON CATEGORY 4: VERY STRONG TYPHOON
MSW: 131-155 mph (114-135 kt)
Peak Gusts: 166-197 mph (145-171 kt)

Potential Damage - Some reinforced hollow-spun concrete and many reinforced wooden power poles blown down; numerous secondary and a few primary power lines downed. Extensive damage to non-concrete roofs; complete failure of many roof structures, window frames and doors, especially unprotected, non-reinforced ones; many well-built wooden and metal structures severely damaged or destroyed. Considerable glass failures due to flying debris and explosive pressure forces created by extreme wind gusts. Weakly reinforced cinderblock walls blown down. Complete disintegration of mobile homes and other structures of lighter materials not tied down. Most small and medium-sized steel-framed signs bent over or blown down. Some secured construction cranes and gantry cranes blown down. Some fuel storage tanks may rupture. Air is full of large projectiles and debris. Shrubs and trees 50-90% defoliated; up to 100% of tangantangan (*Leucaena spp.*) defoliated. Up to 75% of palm fronds bent, twisted, or blown off; many crowns stripped from palm trees. Numerous green and virtually all ripe coconuts blown from trees. Severe damage to sugar cane [*Saccharum spp.*] and bamboo [*Bambusa spp.*]. Many large trees blown down (palms, breadfruit [*Artocarpus spp.*], monkeypod [*Samanea saman*], mango [*Mangifera indica*], acacia [*Acacia spp.*], and Australian pine (*Casuarina spp.*). Considerable bark and some pulp removed from trees; most standing trees are void of all but the largest branches (severely pruned), with remaining branches stubby in appearance; numerous trunks and branches are sandblasted. Patches of panax [*Polyscias spp.*], tangantangan [*Leucaena spp.*], and oleander [*Nerium oleander*] are flattened. Overall damage can be classified as extreme.

Coastal Inundation and Wave Action - On windward coasts, sea level rise of 12-18 ft (3.7-5.5 m) above normal in open bays and inlets due to storm surge and wind-driven waves; breaking waves inside bays can reach 15-25 ft (4.6-7.6 m) above normal; water is about 8-12 ft (2.4-3.7 m) above normal across reef flats. Wind-driven waves will inundate coastal areas below 10-15 ft (3.0-4.6 m) elevation. Large boulders carried inland with waves. Severe beach erosion. Severe damage to port facilities including some loading derricks and gantry cranes. Most ships torn from moorings.

5) TYPHOON CATEGORY 5: DEVASTATING TYPHOON
MSW: 156-194 mph (136-170 kt)
Peak Gusts: 198-246 mph (172-216 kt)

Potential Damage - Severe damage to some solid concrete power poles, to numerous reinforced hollow-spun concrete power poles, to many steel towers, and to virtually all wooden poles; all secondary power lines and most primary power lines downed. Total failure of non-concrete reinforced roofs. Extensive or total destruction to non-concrete residences and industrial buildings. Some structural damage to concrete structures, especially from large debris, such as cars, large appliances, etc. Extensive glass failure due to impact of flying debris and explosive pressure forces during extreme gusts. Many well-constructed storm shutters ripped from structures. Some fuel storage tanks rupture. Nearly all construction cranes blown down. Air full of very large and heavy projectiles and debris. Shrubs and trees up to 100% defoliated; numerous large trees blown down. Up to 100% of palm fronds bent, twisted, or blown off; numerous crowns blown from palm trees; virtually all coconuts blown from trees. Most bark and considerable pulp removed from trees. Most standing trees are void of all but the largest branches, which are very stubby in appearance and severely sandblasted. Overall damage can be classified as catastrophic.

Coastal Inundation and Wave Action - On windward coasts, sea level rise of 18-30+ ft (5.5-9.1+ m) above normal in open bays and inlets due to storm surge and wind-driven waves; breaking waves inside bays can be 25-35+ ft (7.6-10.7 m) above normal; water is about 12-20+ ft (3.7-6.1+ m) above normal across reef flats. Serious inundation likely for windward coastal areas below 15-28+ ft (4.6-8.5+ m) elevation. Very large boulders carried inland with waves. Extensive beach erosion. Extensive damage to port facilities including most loading derricks, gantry cranes, and fuel piers. Virtually all ships, regardless of size, torn from moorings and many run aground or sunk.

A TROPICAL CYCLONE WINDSPEED--DESTRUCTION SCALE FOR THE TROPICAL PACIFIC

TROPICAL CYCLONE CATEGORY	DEBRIS SIZE (in air)	RESIDENTIAL BUILDINGS		GOVERNMENT COMMERCIAL BUILDINGS		INFRASTRUCTURE POWER/PHONE/CABLE TV			INFRASTRUCTURE PORTS OF ENTRY		VEGETATION/ AGRICULTURE	INUNDATION ABOVE HIGH TIDE	
TROPICAL STORM CATEGORIES		Wood	Concrete	Sheet Metal	Concrete	Wood Poles	Concrete Poles	Trans Lines	Sea Port	Air Port	Exposed	Inside Bays Reefs <250'	Over Reefs 250'-500'
TS CAT A Sus: 30-49 mph Gust:40-64 mph **WEAK**	Small leaves and twigs	Thatch damaged	N	N	N	N	N	N	N	Light, unsecured aircraft moved	Salt spray; some serious crop damage	<1'	<1'
TS CAT B Sus; 50-73 mph Gust: 65-94 mph **SEVERE**	Some sheet iron & plywood becomes airborne	Thatch destroyed; poorly attached sheet iron, plywood	N	Gaps in sheet metal begin to open	N	A few un-guyed poles tilt; very rotten may snap	N	A few secondary lines downed	N	Light unsecured aircraft may flip; debris blown on runways	Heavy salt spray; moderate damage to banana trees; severe damage to crops	1-2'	1-2'

A TROPICAL CYCLONE WINDSPEED--DESTRUCTION SCALE FOR THE TROPICAL PACIFIC

TROPICAL CYCLONE CATEGORY	DEBRIS SIZE (in air)	RESIDENTIAL BUILDINGS		GOVERNMENT COMMERCIAL BUILDINGS		INFRASTRUCTURE POWER/PHONE/CABLE TV			INFRASTRUCTURE PORTS OF ENTRY		VEGETATION/ AGRICULTURE	INUNDATION ABOVE HIGH TIDE	
TYPHOON CATEGORY		Wood	Concrete	Sheet Metal	Concrete	Wood Poles	Concrete Poles	Trans Lines	Sea Port	Air Port	Exposed	Inside Bays Reefs <250'	Over Reefs 250'-500'
TY CAT 1 Sus: 74-95 mph Gust: 95-120 mph **MINIMAL**	Many pieces of sheet iron, plywood, palm fronds airborne	Some damage to termite-weakened roofs	Some unprotect windows broken by debris	Gaps in sheet metal made larger & roofing starts to roll	N	Termite-weakened poles begin to snap	Un-guyed hollow begin to tilt	A few 2ndary lines downed	Some small craft torn from moorings; some pier damage	Considerable debris blown onto runways; unhangered light aircraft damaged	Palm fronds begin to crimp through crown, major damage to bananas & crops; <10% defoliation of plants	2-4'	2-3'
TY CAT 2 Sus: 96-110 mph Gust:121-139 mph **MODERATE**	Much sheet iron, limbs plywood, palm fronds, 2X4s airborne	Much damage to termite-weakened roofs, doors, windows	Many unprotect windows broken by debris	Large openings in sheet iron with gaps; edges of well-built roofs leak	Some unprotect windows cracked by debris, some roof tiles damaged	Several termite-weakened poles snap	Several unguyed hollow poles tilt	Many secondary lines downed	Many small craft torn from moorings, considerable pier damage;	Unhangered light aircraft destroyed, heavy aircraft hit by debris; terminal windows cracked	Palm fronds ripped from palm trees; some green coconuts blown from palms; some branches/ limbs snapped; many breadfruit, mangos, etc blown from trees; 10-20% defoliation	4-6'	3-5'
TY CAT 3 Sus:111-130 mph Gust:140-165 mph **STRONG**	Many light and some medium-sized objects become airborne:e.g plywood, sheet iron, 2X4s	Weakly constructd & termite-weakened housed heavily damaged or destroyed	Numerous unprotectd windows broken by debris; exposed A/C damaged	Buildings with gaps in sheet iron heavily damaged or destroyed; edges of well-built roofs leak	Some unprotect windows broken by debris, some roof tiles become airborne	Many snapped/downed; most termite-weakened destroyed	Some unguyed hollow poles snapped/downed	Some primary & most 2ndary lines downed	Some large ships torn from moorings & driven onto reefs; many small craft sunk; empty containers blown	Heavy aircraft damaged by debris; empty containers can become airborne; some terminal windows broken; nav aids damaged	Many green coconuts blown from palms; up to 50% palm fronds bent or torn off, crown of palms begin to blow off, many small limbs snapped; most breadfruit, mangos, etc blown from trees; 20-50% defoliation	6-10'	5-8'

A TROPICAL CYCLONE WINDSPEED--DESTRUCTION SCALE FOR THE TROPICAL PACIFIC

TROPICAL CYCLONE CATEGORY	DEBRIS SIZE (in air)	RESIDENTIAL BUILDINGS		GOVERNMENT COMMERCIAL BUILDINGS		INFRASTRUCTURE POWER/PHONE/CABLE TV			INFRASTRUCTURE PORTS OF ENTRY		VEGETATION/ AGRICULTURE	INUNDATION ABOVE HIGH TIDE	
TYPHOON CATEGORY		Wood	Concrete	Metal	Concrete	Wood Poles	Concrete Poles	Trans Lines	Sea Port	Air Port	Exposed	Inside Bays Reefs <250"	Over Reefs 250'-500'
TY CAT 4 Sus:131-155 mph Gust:166-197 mph **VERY STRONG**	Many medium-sized objects become airborne; e.g., washers, roof tiles, glass	Even well-built structures heavily damaged or destroyed	Numerous windows implode; good shutters survive; doors fail	Most, even well-built structures heavily damaged or destroyed	Most unprotect windows broken by debris; many roof tiles become airborne	Most wood poles downed/ snapped;	Many unguyed and some guyed hollow poles snapped/ downed	Many primary & all 2ndary lines downed	Many large ships torn from moorings & driven onto reefs; empty containers become airborne; cranes heavily damaged	Large aircraft damaged by debris; full containers airborne; many tower & terminal glass broken; hanger doors & nav aids destroyed	Most green coconuts blown from palms; up to 75% palm fronds bent or torn off, many palm crowns blown off, many large limbs snapped; most breadfruit, mangos, etc blown from trees; 50-80% defoliation	10-15'	8-12'
TY CAT 5 Sus:156-194 mph Gust:198-246 mph **DEVASTATING**	Large objects become airborne; e.g., cars, washers	All wooden buildings destroyed	Shutters, windows, doors, A/C fail	All metal buildings destroyed	Some structural damage from large debris; shutters, A/C, destroyed	All wood poles destroyed	Some steel & solid concrete & numerous hollow poles downed	Most primary lines downed	All large ships torn from moorings & driven onto reefs or sunk; full containers become airborne; cranes destroyed	Large aircraft heavily damaged; all terminal windows & doors fail; hangered large aircraft may be damaged	All green coconuts blown from palms; up to 100% palm fronds bent or torn off, numerous palm crowns blown off, many large limbs snapped; most breadfruit, mangos, etc blown from trees; up to 100% defoliation	15-30'+	12-20+'

ABBREVIATIONS

WP – wooden electrical pole
CP – concrete electrical pole
Line – electrical lines
PRT – commercial port
AP – international airport
2ndary – refers to secondary electrical lines and phone and cable TV lines

TROPICAL STORMS AND TYPHOONS PASSING WITHIN 75 N Mi OF GUAM (TIYAN), 1945-1997

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	KATE	1945	OCT	1	22	43	68 (NNW)	302/11.4
2	LOUISE	1945	OCT	4	23	40	59 (NNW)	295/15.3
3	OPAL	1946	SEP	7	10	60	47 (S)	286/18.3
4	QUERIDA	1946	SEP	20	12	103	23 (NNW)	283/17.9
5	AGNES	1948	NOV	14	23	65	47 (NNW)	285/15.1
6	ALLYN	1949	NOV	17	20	124	60 (SSE)	290/16.7
7	MARGE	1951	AUG	11	7	65	22 (SSE)	290/ 8.4
8	POLLY	1952	SEP	27	15	34	72 (NW)	309/16.7
9	AGNES	1952	OCT	30	21	34	4 (NW)	320/10.5
10	BESS	1952	NOV	9	22	34	40 (NNW)	292/13.2
11	IRMA	1953	FEB	21	2	75	72 (SSE)	300/12.3
12	NINA	1853	AUG	10	8	75	22 (NNW)	301/12.2
13	ALICE	1953	OCT	14	19	50*	28 (N)	276/10.7
14	IDA	1954	AUG	24	6	55	2 (NNW)	287/19.7
15	TILDA	1954	NOV	26	19	70	41 (S)	287/ 9.8
16	MARGE	1955	SEP	27	16	50	35 (ESE)	326/21.5
17	HESTER	1957	OCT	5	15	60	22 (NNW)	339/10.7
18	LOLA	1857	NOV	15	20	150	41 (S)	280/13.9
19	VIOLA	1958	JUL	9	6	60*	50 (ESE)	330/ 7.7
20	IDA	1958	SEP	20	18	55*	9 (S)	273/16.6
21	KAREN	1962	NOV	11	27	135	11 (S)	269/17.1
22	NADINE	1962	DEC	8	30	34	5 (NNE)	069/ 8.1
23	OLIVE	1963	APR	29	1	124	35 (ENE)	023/ 5.9
24	LOLA	1963	OCT	10	19	34	1 (N)	270/11.9
25	SUSAN	1963	DEC	24	25	123	65 (NNW)	285/12.0
26	ALICE	1984	JUN	26	4	40	49 (SSE)	286/ 7.1
27	SALLY	1964	SEP	5	21	89	13 (SSE)	287/20.4
28	HARRIET	1965	JUL	22	14	35	42 (SE)	320/12.1
29	DINAH	1967	OCT	17	30	55	47 (S)	264/19.6
30	GILDA	1967	NOV	13	33	120	46 (NNW)	286/11.1
31	IRMA	1968	OCT	22	21	46	21 (NNW)	288/ 8.6
32	ORA	1968	NOV	22	27	45	5 (SSE)	283/19.5
33	PHYLLIS	1969	JAN	22	1	35	1 (N)	272/19.5
34	PAMELA	1976	MAY	21	6	120	3 (SE)	319/ 7.7
35	FRAN	1976	SEP	5	17	47	30 (SE)	324/12.7
36	GEORGIA	1976	SEP	12	18	35	70 (S)	264/11.8
37	KIM	1977	NOV	8	19	63*	6 (N)	277/15.7
38	JUDY	1979	AUG	16	13	34	12 (SSE)	291/14.1
39	TIP	1979	OCT	9	23	58*	43 (S)	274/14.7
40	WYNNE	1980	OCT	6	23	46	55 (WNW)	332/10.8
41	BETTY	1980	OCT	30	25	71	31 (S)	280/19.7
42	GERALD	1981	APR	18	2	43	72 (WSW)	018/ 8.4
43	HAZEN	1981	NOV	15	25	60	88 (NNE)	241/13.8
44	IRMA	1981	NOV	19	26	40	25 (N)	274/ 8.8
45	KIT	1981	DEC	13	28	55	64 (S)	275/10.8
46	JUDY	1982	SEP	5	19	34	53 (S)	270/ 9.8
47	MAC	1982	OCT	2	23	58*	28 (SSE)	289/10.2
48	BILL	1984	NOV	12	28	83	26 (SSE)	284/19.1
49	PEGGY	1986	JUL	4	7	62*	69 (N)	275/11.7
50	CARMEN	1986	OCT	3	17	51	61 (NNW)	292/13.6
51	THELMA	1987	JUL	8	5	37	74 (N)	281/17.0
52	ROY	1988	JAN	12	1	110	24 (N)	276/12.9
53	WARREN	1988	JUL	13	6	35	71 (S)	278/ 9.9
54	KORYN	1990	JAN	14	1	65	49 (WNW)	344/ 6.2
55	RUSS	1980	DEC	20	31	122	55 (SSE)	285/12.1
56	OMAR	1992	AUG	28	16	105	1 (SSE)	285/ 8.0
57	BRIAN	1992	OCT	21	26	85	8 (SE)	309/ 7.7
58	ELSIE	1992	NOV	2	29	93	70 (SSE)	300/ 7.9
59	GAY	1992	NOV	23	32	90	5 (S)	271/14.6
60	HUNT	1992	NOV	18	33	65	21 (NW)	306/11.2
61	ED	1993	SEP	30	26	38	7 (NNW)	298/ 8.6
62	NAT	1994	SEP	15	27	35	43 (N)	080/10.9
63	ORCHID	1994	SEP	19	28	38	54 (E)	360/ 9.3
64	VERNE	1994	OCT	18	33	48	58 (N)	279/12.8
65	ELI	1995	JUN	4	4	38	27 (SSE)	292/10.2
66	WARD	1995	OCT	17	26	57	66 (NNW)	284/16.0
67	IAN	1996	JUL	27	11	34	47 (E)	358/ 8.2
68	BING	1997	AUG	29	19	42	31 (NNW)	288/13.2
69	IVAN	1997	OCT	14	28	53	57 (S)	279/15.9
70	KEITH	1997	NOV	2	30	143	69 (NNW)	285/15.1
71	PAKA	1997	DEC	16	33	129	13 (N)	270/ 5.8

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach (CPA) to site. Maximum winds are at time of CPA. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 knots) somewhere within 75 nautical mile radius of site but not at CPA. Location of site is 13.48°N, 144.80°E.

CHART 1A

TYPHOONS PASSING WITHIN 75 NMi OF GUAM (TIYAN), 1945-1997

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	GUERIDA	1946	SEP	20	12	103	23 (NNW)	283/17.9
2	AGNES	1948	NOV	14	23	65	47 (NNW)	285/15.1
3	ALLYN	1949	NOV	17	20	124	60 (SSE)	290/16.7
4	MARGE	1951	AUG	11	7	65	22 (SSE)	290/ 8.4
5	IRMA	1953	FEB	21	2	75	72 (SSE)	300/12.3
6	NINA	1953	AUG	10	8	75	22 (NNW)	301/12.2
7	ALICE	1953	OCT	14	19	50*	28 (N)	276/10.7
8	TILDA	1954	NOV	26	19	70	41 (S)	287/ 9.8
9	LOLA	1957	NOV	15	20	150	41 (S)	280/13.9
10	VIOLA	1958	JUL	9	6	60*	50 (ESE)	330/ 7.7
11	IDA	1958	SEP	20	15	55*	9 (S)	273/16.6
12	KAREN	1962	NOV	11	27	135	11 (S)	269/17.1
13	OLIVE	1963	APR	29	1	124	35 (ENE)	023/ 5.9
14	SUSAN	1963	DEC	24	25	123	65 (NNW)	285/12.0
15	SALLY	1964	SEP	5	21	89	13 (SSE)	287/20.4
16	GILDA	1967	NOV	13	33	120	46 (NNW)	286/11.1
17	PAMELA	1976	MAY	21	6	120	3 (SE)	319/ 7.7
18	KIM	1977	NOV	8	19	63*	6 (N)	277/15.7
19	TIP	1979	OCT	9	23	58*	43 (S)	274/14.7
20	BETTY	1980	OCT	30	25	71	31 (S)	280/19.7
21	MAC	1982	OCT	2	23	58*	28 (SSE)	299/10.2
22	BILL	1984	NOV	12	28	83	26 (SSE)	284/19.1
23	PEGGY	1986	JUL	4	7	62*	69 (N)	275/11.7
24	ROY	1988	JAN	12	1	110	24 (N)	276/12.9
25	KORYN	1990	JAN	14	1	65	49 (WNW)	344/ 6.2
26	RUSS	1990	DEC	20	31	122	55 (SSE)	285/12.1
27	OMAR	1992	AUG	28	16	105	1 (SSE)	285/ 8.0
28	BRIAN	1992	OCT	21	26	65	8 (SE)	309/ 7.7
29	ELSIE	1992	NOV	2	29	93	70 (SSE)	300/ 7.9
30	GAY	1992	NOV	23	32	90	5 (S)	271/14.6
31	HUNT	1992	NOV	18	33	65	21 (NW)	306/11.2
32	KEITH	1997	NOV	2	30	143	69 (NNW)	285/15.1
33	PAKA	1997	DEC	16	33	129	13 (N)	270/ 5.8

NOTES:

Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach (CPA) to site. Maximum winds are at time of CPA. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 knots) somewhere within 75 nautical mile radius of site but not at CPA. Location of site is 13.48°N, 144.80°E.

CHART 18