Mitigating Noise from Open Detonations at China Lake

Seasonal & Monthly Analyses Lead to Plan that Minimizes Impacts to Local Communities

ROBUST SEASONAL AND monthly analysis of sound propagation levels have enabled personnel from Naval Air Weapons Station (NAWS) China Lake, California to develop and execute a solid plan that minimizes impacts to the surrounding communities of the sound generated during open detonation events.

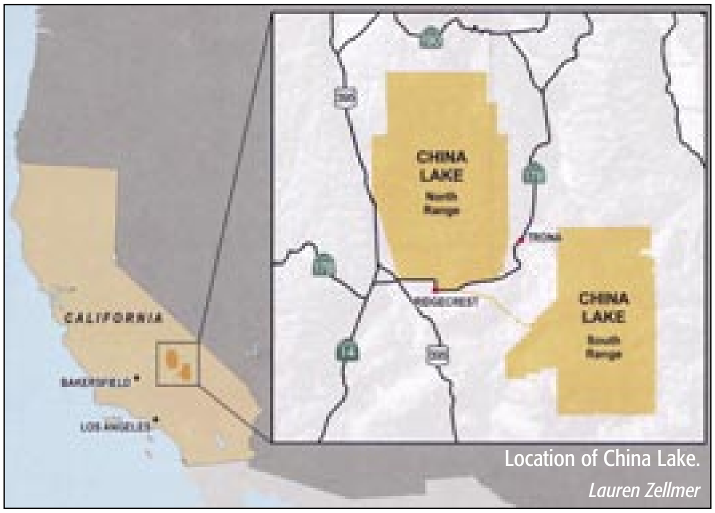
NAWS China Lake is the Navy's largest Research, Development, Acquisition, Test, and Evaluation facility for weapons development and testing. As a result of its mission activities, China Lake generates a diverse and explosive wastestream—most of which is destroyed via open detonation (OD).

In order to comply with environmental and safety regulations, the California Environmental Protection Agency required China Lake to apply for a Part B permit—a modification of the base's existing hazardous waste facility permit. The Part B permit application developed by NAWS personnel addressed mitigation of potential human health risks and environmental impacts of OD events, including noise. The Part B permit was granted in 2008, and the noise analysis was begun as a condition of that permit.

Sources of noise at China Lake include airfield operations, aircraft flights (both subsonic and supersonic), sonic booms, and ordnance detonation at test and target sites. These activities can create high noise levels which may impact surrounding areas. An Air Installation Compatible Use Zones (AICUZ) program plan is used to achieve compatibility between the NAWS China Lake and surrounding communities by

The Basics About China Lake

NAWS CHINA LAKE is the principal Navy research, development, test, and evaluation center for air warfare systems (except antisubmarine warfare systems) and missile weapons systems. The NAWS manages and conducts the complete weapon development process, from concept formulation through the entire lifetime of a weapon system, including fleet and production support. Nearly every significant Navy and Marine Corps airborne weapon system in the past five decades was developed and/or tested at China Lake.



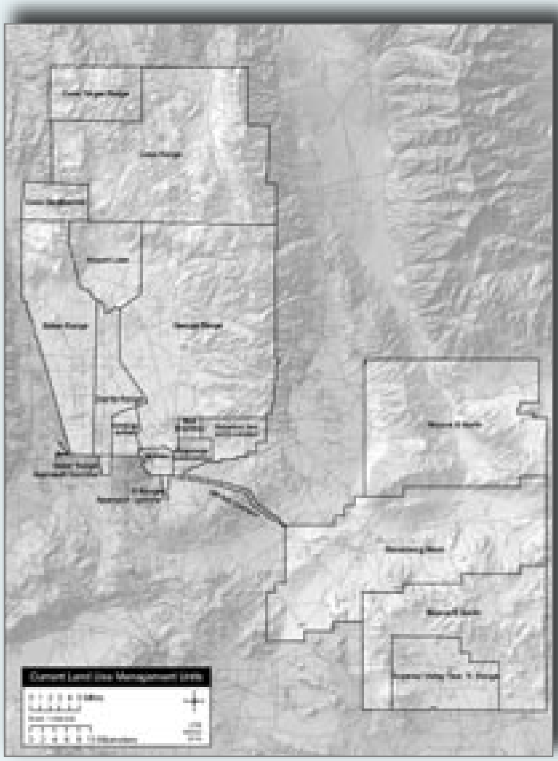
Location of China Lake.
Lauren Zellmer

The Basics About Open Detonation

BECAUSE A LARGE percentage of energetic hazardous waste (EHW) generated at China Lake is either hazardous, incompletely classified, or altered by research and development activities, Federal and Navy regulations prohibit the transport of most of this EHW via public roadways. As a result, most of this EHW must be treated onboard China Lake.

Currently, OD is the primary and preferred method of treating EHW at China Lake. Open burning can also be conducted; however, hazard analyses have determined that OD is the preferable method for treating sensitive research compounds and damaged ordnance items. China Lake operates one site to conduct all of its OD events. This single site is environmentally desirable because the base itself covers a huge landmass, and much of the surrounding land is either owned or controlled by the United States government. The arid landscape and deep groundwater level—more than 400 feet below surface—minimizes the risk of soil and groundwater contamination, and the nearest surface water is four miles away, on base property. Additionally, the site is located in rocky terrain outside of the known habitat of the desert tortoise.

Nationwide, many OD treatment facilities bury waste items to mitigate blast effects and noise. However, this method prevents the complete conversion of toxic compounds to nontoxic compounds. To ensure that toxic compounds are completely neutralized, a larger amount of donor explosive and exposure to air are needed. This is possible at China Lake because the base is so large, and its OD facility is seven miles from the base's fenceline.



Location of the OD site in China Lake's north range.
Lauren Zellmer

managing noise. (See our sidebar entitled, "The Basics About Air Installation Compatible Use Zones.") However, this plan applies to aircraft and training-related noise only—hence the need for a separate sound analysis.

Conducting the Noise Analysis

The noise analysis mandated by the permit B application was a collaborative effort among personnel from China Lake and Wyle Laboratories. Wyle used Noise Model Simulation (NMSim) and ground elevation data for the area, as well as the Noise Assessment Prediction Capability (NAPS) developed by the U.S. Army. This software provides an estimate of the surface peak noise intensity in all directions surrounding a blast source while accounting for meteorological and topographical variations.

The effort began by dividing single-blast effects into "annoyance" and "structural damage" categories. A threshold for annoyance events, also known as "knick-knack shakers," has been established by the American National Standards Institute at 120 decibels (dB). This is roughly the noise level of a jet engine. The lowest documented threshold for structural damage is 128 dB. Though NAWS China Lake's permit only required an analysis of blasts with the potential for structural

The Basics About Air Installation Compatible Use Zones

IN THE EARLY days of aviation, military airfields were situated in remote areas, far from civilian populations. However, in the post-World War II baby boom, communities began to encroach upon military bases. This type of encroachment increased the safety risk and level of annoyance experienced by civilian populations. Navy experience over the years has demonstrated that the presence of these factors invariably results in restrictions being imposed on the conduct of military operations, thereby adversely impacting the ability of an installation to fulfill its mission. In the early 1970s, the Department of Defense (DoD) initiated the AICUZ program to address this problem. Each base with an operational airfield is required by DoD instruction 4165.57 to develop an AICUZ study.

In an AICUZ study, noise exposure zones and accident potential zones are generated from computer models and historical operational data. These zones are used as planning tools for installation and local government agencies in an effort to prevent development or land uses that could endanger aircraft or the public in the vicinity of the airfield.

The China Lake AICUZ study, for example, addressed the following considerations when issuing land use recommendations:

- Lighting (direct or reflected) that would impair pilot vision
- Towers, tall structures, and vegetation that penetrate navigable airspace or are to be constructed near the airfield
- Land uses that would generate smoke, steam, or dust
- Land uses that would attract birds, especially waterfowl
- Electromagnetic interference with aircraft communications, navigation, or other electrical systems

Once noise exposure zones and accident potential zones (APZ) are determined in an AICUZ study, command personnel turn to Chief of Naval Operations Instruction 11010.36C, "Air Installations Compatibility Use Zones Program," for land-use compatibility recommendations. For example, manufacturing may be allowed in zones where residential development is discouraged.

The China Lake AICUZ has a detailed land-use plan, based on three different noise zones and two APZs.

damage, both thresholds were used in the noise analysis for the OD facility.

Pile of EHW ready for OD treatment.
Lauren Zellmer

How Noise Travels

Noise from OD consists of vibrations from blasts traveling from the source to the receiver through the ground and air. Since the OD facility is approximately ten miles from the nearest towns (Trona and Ridgecrest), ground-borne vibration from OD events is unlikely to be sufficient to cause structural damage. Therefore, the noise analysis focused on airborne vibrations.

To determine the conditions under which airborne vibrations were likely to travel farthest, historical meteorological data were collected and organized into the four seasons of the year.

Utilizing the maximum allowable OD blast of 22,500 pounds Net Explosive Weight (NEW), the analysis determined that peak sound levels exceed the 128 dB threshold off-China Lake only during the winter season. (NEW refers to the actual weight of explosive. 22,500 pounds NEW is the TNT-equivalent of 15,000 pounds.)

Atmospheric conditions can have a strong effect on sound propagation, particularly over long distances. While humidity and temperature have a substantial effect on sound propagation, temperature inversions and positive wind gradients have a greater effect.

A temperature inversion means that temperatures are cooler at ground level and warmer at higher altitudes. Sound can refract or bend downward during temperature inversion conditions and/or when the propagation is downwind.

View of the OD blast site from a distance of one mile.
Lauren Zellmer

A positive wind speed gradient is a condition when wind speed increases with increasing altitude. This condition also causes sound waves to refract, pushing them greater distances.

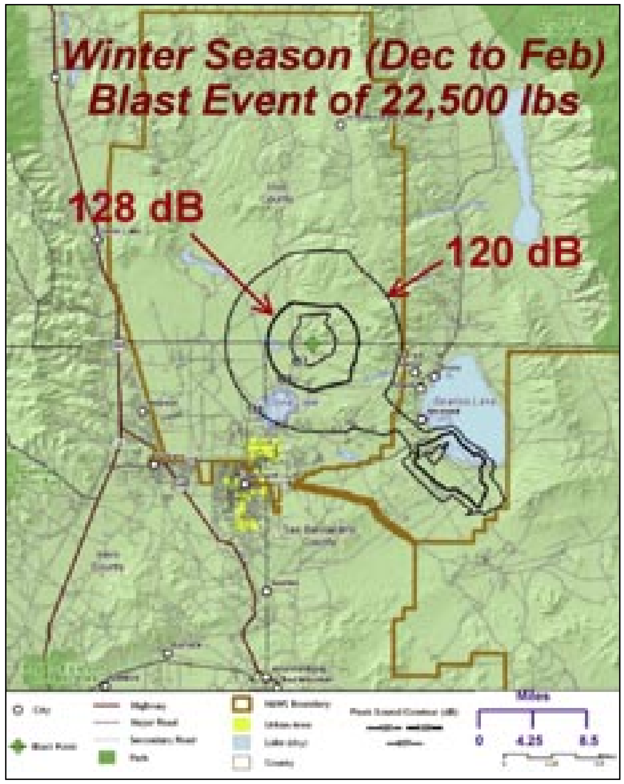
Assessing the Data

Several years of meteorological data were collected and examined. The seasonal data were first examined to determine when a temperature inversion was present. Temperature inversion was not found to be present in any average seasonal data, including winter.

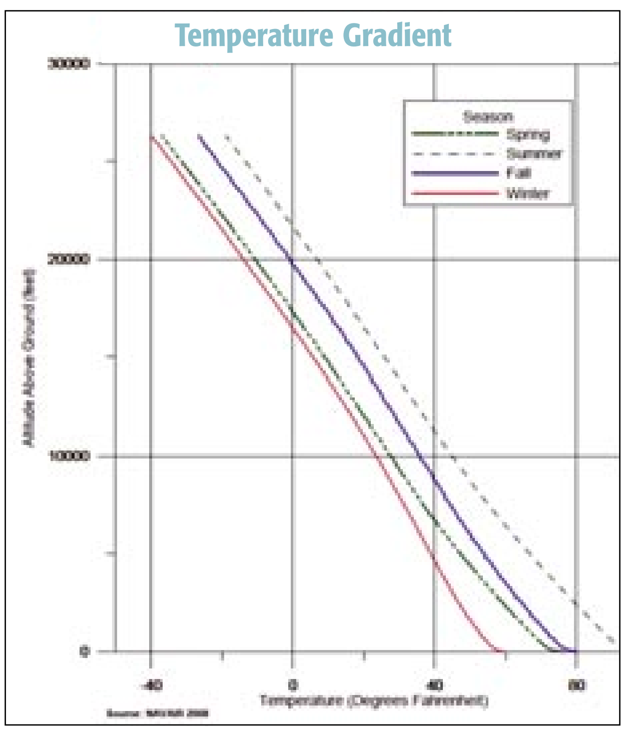
The temperature gradient plotted on the chart at right describes a condition called temperature lapse, which is the opposite of temperature inversion.

The seasonal meteorological data was next examined to determine when a positive wind gradient was present. All seasons indicated a positive wind gradient.

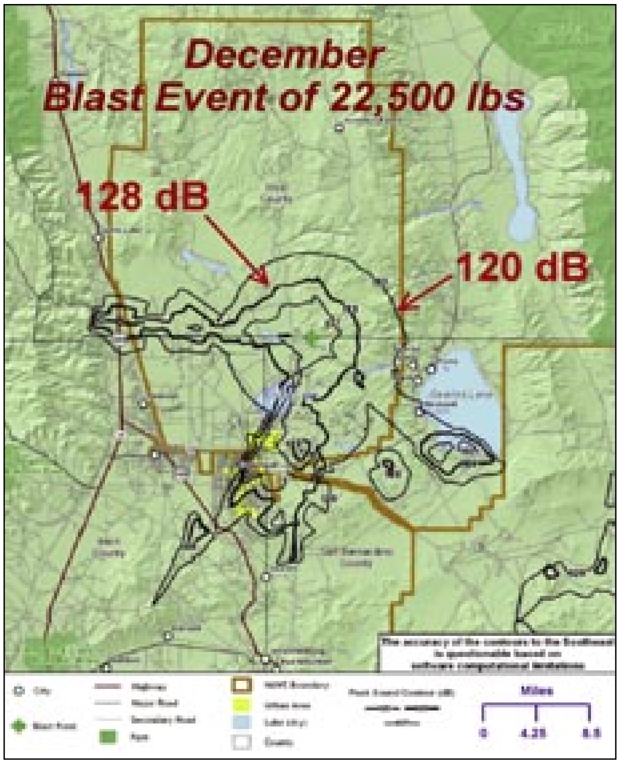
The rate of increase during the spring, summer, and fall seasons is not significant to produce downward refraction. The rate of increase is, however, significant during the winter season, increasing sound propagation along the ground. This positive wind speed gradient during the winter season is the primary contributing meteorological condition to off-China Lake noise levels.

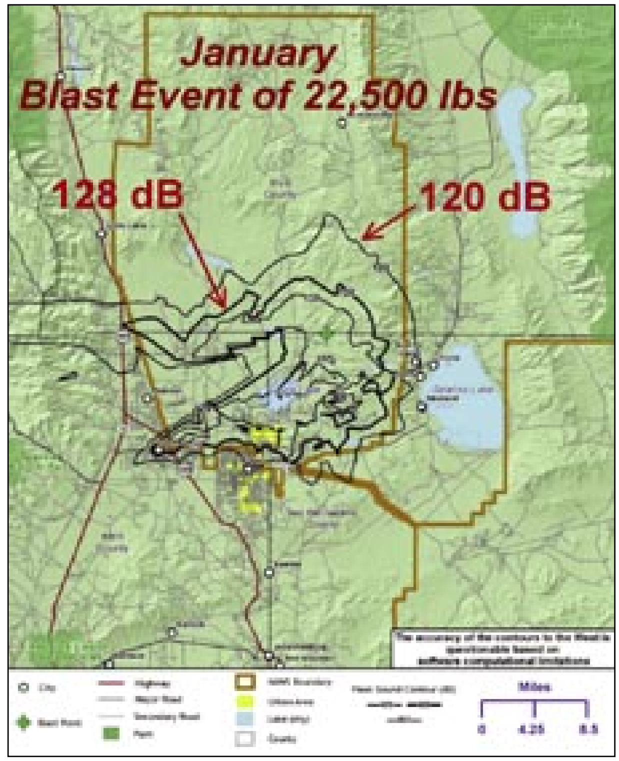


It was found that sound traveled furthest in winter, exceeding peak threshold sound levels of 128 dB in an area off-China Lake. (Bold lines represent 128dB; gold lines represent base boundaries.)



In this condition, the temperature increases closer to the ground. Temperature lapse favors sound refraction up and away from the ground, reducing the ability of sound to travel.

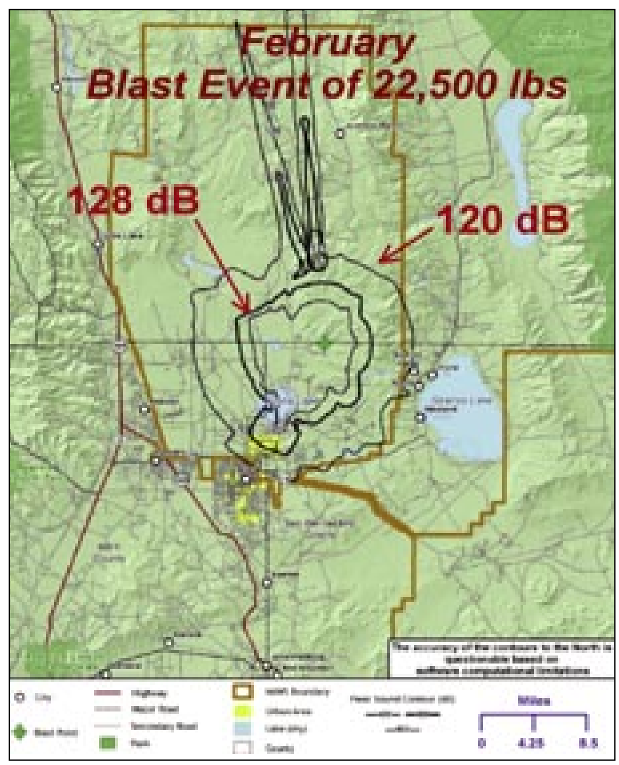




Next, monthly metrological data were examined to calculate peak sound levels during each winter month (December, January, and February). All three winter months show positive wind gradients. While no significant temperature inversions are indicated, it is important to note that strong temperature inversions may be present during certain times of a particular day (most typically mornings). Strong inversions produce significant downward refraction of sound waves, and longer distance sound propagation.

It was found that a positive wind gradient is likely to cause downward refraction of sound waves and longer distance sound propagation during all the winter months for a normal 22,500-pound event.

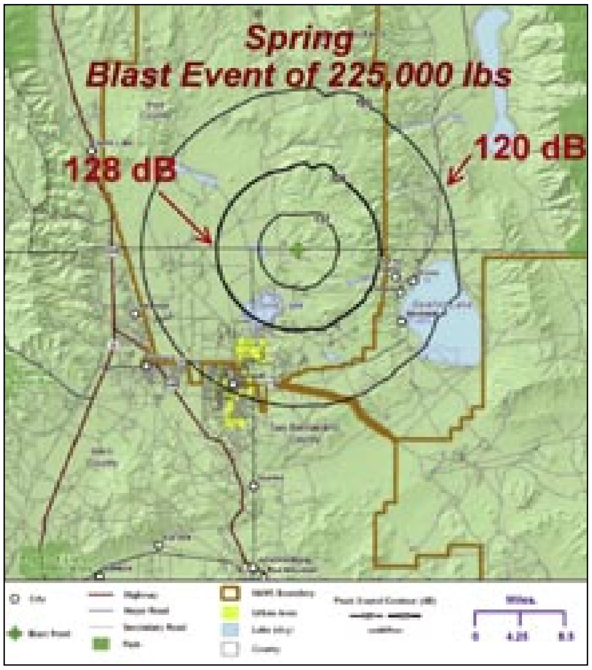
Increasing the size of the blast did not appear to increase sound propagation significantly. Although blast events are limited to 22,500 NEW at China Lake, larger blasts of 100,000 and 250,000 pounds NEW were modeled on an experimental basis. The results show a similarity of contours.

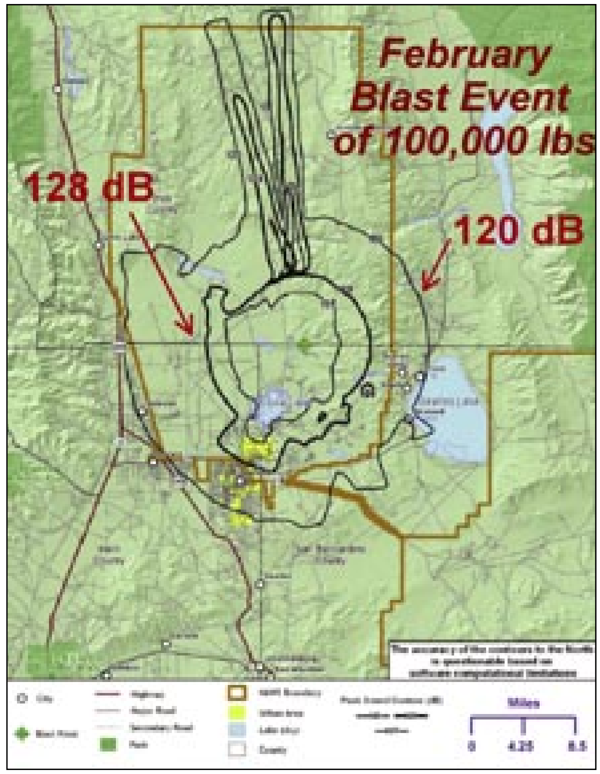


These maps demonstrate how peak sound levels in December, January and February occasionally reached 128 dB in surrounding communities (see bold lines). Note that the contours for February are quite different than those for December and January. This difference is probably due to a smaller set of metrological data for February as compared to the data set for December and January.

The Findings

After collecting and analyzing more than three years' worth of meteorological data, it was determined that the





Though blast events are limited to 22,500 NEW at China Lake, larger blasts were demonstrated. Surprisingly, the annoyance and structural damage zones did not differ significantly with these more powerful blasts.

Temperature inversion is typically not a factor between 10:00 am and sundown.

potential for unacceptable off-China Lake noise exposure for single-event detonations is driven by two adverse weather conditions:

1. Temperature inversion
2. Positive wind gradient (winds 15 miles per hour (mph) or greater directed toward a populated area)

Temperature inversion is typically not a factor between 10:00 am and sundown. Because almost all OD events occur after 10:00 am, temperature inversion is not considered in OD event planning.

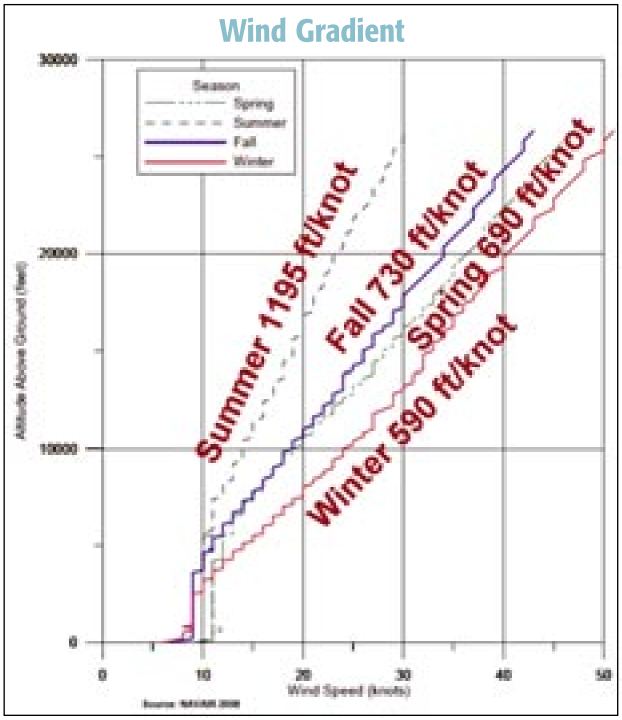
The Mitigation Plan

To assure acceptance of their noise mitigation plan, officials at China Lake worked closely with the local regulator from the State of California Department of Toxic Substances Control, utilizing Wyle as a facilitator. The plan stipulates that the following conditions be studied before an OD event is conducted:

- Wind speed and direction

  From March through November, a favorable wind direction at the surface is towards the West to East/Northeast (90 through 247.5 degrees). This range is favorable with any wind speed, since wind gradient during this time period is not generally an issue.

  During the months of December through February, if wind speeds are 15 mph or less, the same wind direction range (90 through 247.5 degrees) is used. If wind speed is between 15 and 30 mph during December and January, then the more restricted wind direction of



This chart shows a positive wind gradient for each of the four seasons (wind speed on x-axis versus altitude on y-axis).

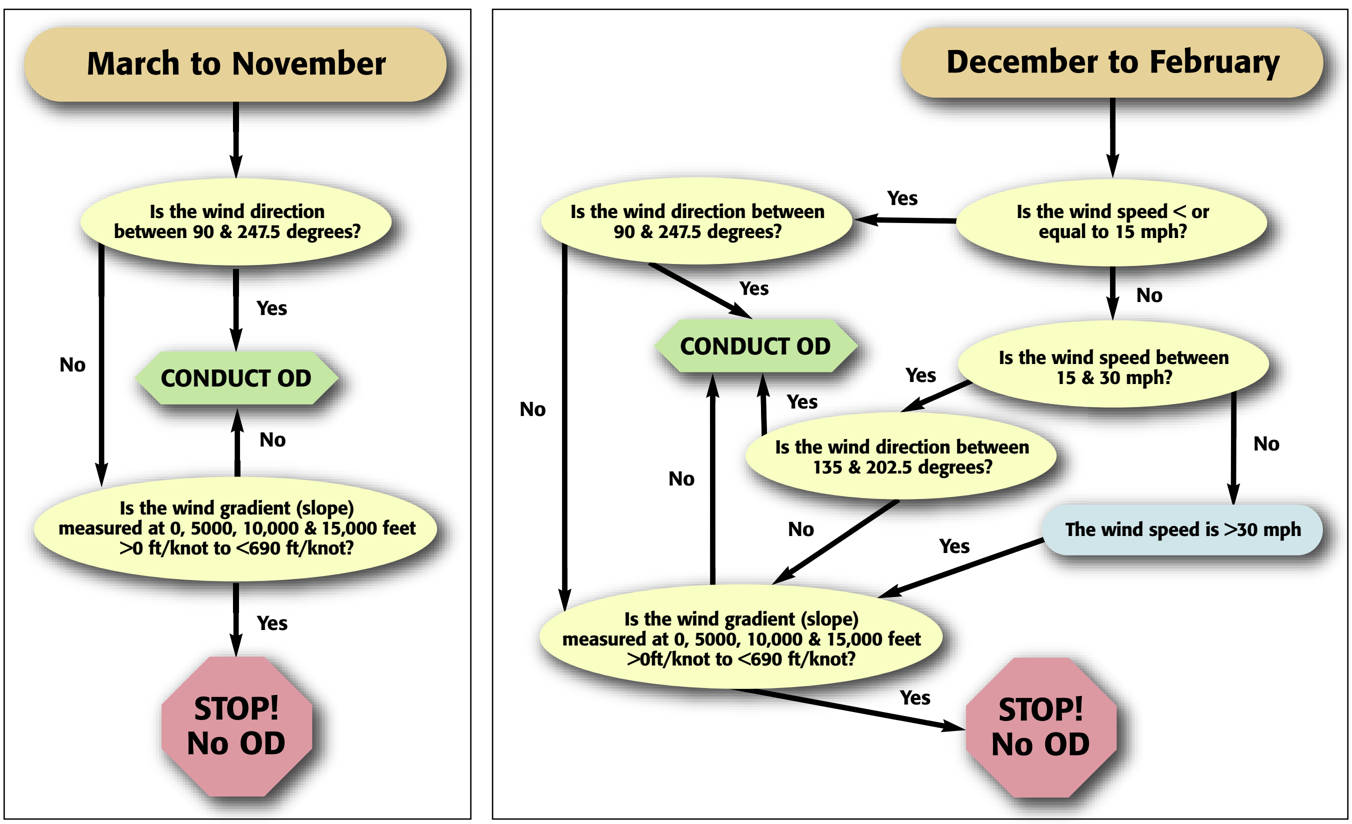
Northwest to North/Northeast (135 through 202.5 degrees) is used.

If the wind direction (along with wind speed) is unfavorable, then the second condition of wind gradient must be considered. (Note: If wind speed in any direction is over 30 knots in December through February, then wind gradient must always be considered.)

- Wind gradient

  As stated earlier, a positive wind gradient increases the refraction of noise. Wind gradient is a measurement of wind speed in knots (x- axis) to altitude in feet (y-axis). As a positive wind gradient means that wind speeds are stronger at higher altitudes and slower at lower altitudes.

In a positive wind gradient, the wind speed increases at elevation, displaying as a decreased slope. The line for the spring season has a slope of 690 feet per knot (ft/knot) and is considered favorable. Any line with a shallower slope (or lower number) than the spring season is considered unfavorable. Therefore, any positive



LEFT: Flowchart for determining noise impacts for spring, summer, and fall months.
RIGHT: Flowchart for determining noise impacts for winter months.

An OD event at China Lake.
China Lake Technical Information Department

More About Wind Speed

A KNOT IS a unit of speed equal to one nautical mile (1.15 land miles). In meteorology, wind speed is always measured in knots. Traditionally, aircraft and ship speeds are also expressed in knots. However, in order to facilitate understanding by the general public, knots are often converted to miles per hour (or kilometers per hour, depending on the local standard). To convert:

- 1 knot equals 1.15 mph
- 1 mph equals 0.868 knots

slope (greater than zero ft/knot) less than 690 ft/knot is considered unfavorable.

If wind speeds do not consistently increase with increase in altitude, a negative wind gradient slope may occur. A negative slope indicates a decrease in wind speed with elevation. This scenario is actually a favorable wind gradient, decreasing the probability that any noise will propagate off-China Lake.

Putting the Plan into Action

As a result of this analysis, China Lake has developed a noise mitigation plan that is executed as part of the base's OD event planning activities. This plan specifies that personnel from the base's environmental office must contact the base Geophysics Operations Division no later than noon of the day before a planned OD event. The office provides wind speed information at various altitudes and wind direction data. This data is input into a simple Excel™ flow chart. This model plots points and calculates slope. If unfavorable conditions are detected, the OD event will be postponed.

Lessons Learned

While it is intuitive to think that the amount of explosives in an OD event is the driving factor for off-station sound propagation, the China Lake noise analysis proved that atmospheric conditions are actually the main driver. Temperature inversion (the same condition that entraps smog into a valley or causes a cold day at low altitudes while warmer at higher altitudes) makes perfect sense as one of the drivers. However, positive wind gradients were not expected as a second driver.

Except for the occasional temperature inversion that lingers into the late morning, China Lake's noise mitigation plan has successfully prevented noise from OD events from reaching surrounding communities. And while meteorological conditions differ widely in other parts of the country, some of the basic findings could prove useful if other facilities are tasked with the challenge of mitigating noise from their own operations. ⚓

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