STATE OF CALIFORNIA

Energy Resources Conservation
And Development Commission

DOCKET
02-AFC-1
DATE JUL 27 2005
RECD. JUL 27 2005

In the Matter of:	)	Docket No. 02-AFC-01
	)	
Application for Certification	)	
for the BLYTHE ENERGY PROJECT, PHASE II	)	
	)	
	)	

Energy Commission Staff's List of Exhibits and Additional Conditions of Certification

Energy Commission staff (Staff) will be referring to the documents listed in attachment A during the evidentiary hearings. Those documents that have not been previously docketed are attached.

Staff is also proposing three additional conditions of certification, included attachments B-D. The first condition, included in attachment B, pertains to the issue of Land Use and is the same condition that was adopted in the Blythe Energy Project (BEPI) proceedings. It would not allow the project owner to permanently retire Prime Farmlands, Farmlands of Statewide Importance, or lands included in a Williamson Act Preserve under the Water Conservation Offset Program (WCOP). This condition is needed to ensure that implementation of the WCOP does not result in significant adverse impacts to farmland and was inadvertently left out of the Final Staff Assessment.

The second condition, included in attachment C, is staff's proposed changes to the Transmission System Engineering condition proposed by applicant in its testimony. Staff has deleted some language it felt unnecessary and added a verification section to corroborate satisfaction of the condition.

The third condition, contained in attachment D, pertains Biological Resources and is supported by supplemental testimony responding to the applicant's decision to use a zero liquid discharge-to-solids system. Since the applicant wishes to retain the evaporation pond to use when maintenance is necessary on the wastewater treatment system, a condition of certification is necessary to ensure that use of the evaporation ponds does not result in any significant adverse impact to biological resources.

Dated: July 27, 2005

Respectfully submitted,

LISA M. DECARLO
Staff Counsel

Proof of Service (Revised 7-1-05) **filed with original.**
Mailed from Sacramento on 7-27-05.
C. Hi

ATTACHMENT A

Biological Resources

Declaration and Resume of Elizabeth Hubert

Soil and Water Resources

BEP I 2002. Blythe Energy Project (99-AFC-8). Parcel B Storm Water Drainage Calculations, Prepared by Burns and Roe Enterprises, Inc., July 2002.

BEP I 2003. Blythe Energy Project (99-AFC-8). Supplementary Storm Water Drainage Calculations, Prepared by Burns and Roe Enterprises, Inc., April 2003.

NRCS 2003. Comments on land management measures for Blythe Energy Project II – Water Conservation Offset Plan. United States Department of Agriculture, Natural Resources Conservation Service. September 2003.

CRB 2002. Letter to Bill Pfanner of the Energy Commission from Gerald Zimmerman, Executive Director of the Colorado River Board of California dated November 15, 2002.

CRB 2003. Letter to Terrence O'Brien of the Energy Commission from Gerald Zimmerman, Executive Director of the Colorado River Board of California dated September 11, 2003.

GEA 2003. GEA Power Cooling Systems. Budgetary information for various Air Cooled Condenser designs and hybrid design for Blythe II Energy Project. E-mail communication from Brendon Tallon of GEA Power Cooling Systems Inc., to Energy Commission c/o Pacific Group Electric Power. May 2003.

PVID 2003d. Water quality test results performed by DANR Analytical Laboratory of PVID irrigation supply and drainage return water in September 2002 and on March 14, 2003.

Various graphics created by expert witness Linda Bond:

- Palo Verde Mesa – Groundwater Quality Sampling
- Hydrology of Palo Verde Valley
- Hydrology of Groundwater Pumping in the Palo Verde Mesa
- Upwelling of Salinity
- Palo Verde Valley – Water Quality Sampling in PVID Surface Drains
- Palo Verde Mesa Wells Sampled for Salinity Over Time

Traffic and Transportation

CASA (Civil Aviation Safety Authority of Australia) 2004. Advisory Circular AC 139-05(0). Guidelines for Conducting Plume Rise Assessments. June 2004.

Katestone (Katestone Environmental). 2003. Aviation Safety and Buoyant Plumes. Peter Best, et al. 2003.

Lester (Peter Lester). 2001. Weather Aviation. Chapter 12 Turbulence. http://cmsu2.cmsu.edu/public/classes/Avia%20Weather/Chapter%2012.ppt, power point summary. 2nd Edition. 2001.

Department of Transportation. Letter to Terrence O'Brien of the California Energy Commission from R. Austin Wiswell, Chief of the California Department of Transportation's Division of Aeronautics dated March 24, 2004.

Department of Transportation. Letter to Terrence O'Brien of the California Energy Commission from Robert A. Wiswell, Chief of the California Department of Transportation's Division of Aeronautics dated March 11, 2005.

Various Charts created by expert witness Will Walters:

- Calm Wind Frequency by Hour
- Calm Wind Monthly Occurrence
- Calm Winds Versus Ambient Temperature
- Cooling Tower Plume Rise A/B/C/D Stability 1 M/S
- HRSG Plume Rise A/B/C/D Stability at 1 M/S

Arnold, Bill. 2004. Photograph of Blythe Energy Power Plant and Blythe Energy Project – Phase 2 Proposed Site – 3,000 feet above ground level.

Map identifying Blythe Airport Safety Zones.

Socioeconomics

M. Cubed. Socioeconomic Assessment of the Proposed Palo Verde Irrigation District Land Management, Crop Rotation and Water Supply Program. Final Report, September 30, 2002, revised on October 2, 2002. Prepared for Palo Verde Irrigation District.

ATTACHMENT B

LAND-6 The proposed water conservation offset program shall not retire lands in the Palo Verde Valley (Priority 1 Lands) designated as Prime Farmlands or Farmlands of Statewide Importance as defined by the Department of Conservation, or lands included in a Williamson Act Preserve. Fallowing or retirement of farmlands shall not violate any provision of a Williamson Act Contract. Lands selected for retirement on the Mesa shall not include lands currently involved in active orchard crop production.

Verification: At least 60 days prior to implementation of the Water Conservation Offset Program (WCOP), the project owner shall submit detailed information to the CPM regarding the lands involved in the WCOP, including: 1) location and assessor parcel number, 2) Department of Conservation Important Farmland Program Classification, 3) crop and cultivation history, and 4) Williamson Act Preserve and contract status. If the program will fallow or retire any lands under Williamson Act contract, the project owner shall provide documentation that such fallowing or retirement has been reviewed and approved by Riverside County Planning Department and does not violate any provision of a Williamson Act contract. Any WCOP agreements that are altered or added to the program shall be submitted to the CPM at least 30 days prior to taking effect.

ATTACHMENT C

TSE-9 The Project Owner shall not commence construction of the Plant until the Desert Southwest Transmission Project (DSWTP) ~~(~~or an equivalent transmission Project or Upgrade as determined by the CPM~~)~~ has received all necessary permits~~.~~ to build the Project and has a definite schedule to commence and complete construction of the Transmission project as determined by the CPM. ~~The Project Owner shall not deliver to the grid more than 520 megawatts combined from BEP and BEP II until the Desert Southwest Transmission Project (or an equivalent transmission upgrade as determined by the CPM) has been constructed and is in operation. The Project Owner shall implement a remedial action scheme as described in the Wester Area Power Administration System Impact Study to curtail total generation from the BEP and BEPII projects to no greater than 520 megawatts in the event of an outage of the Desert Southwest Transmission Project (or equivalent transmission upgrade as determined by the CPM).~~

Verification: At least 60 days prior to the start of rough grading or any Plant construction , the Project Owner shall submit the following to the CPM:

a) A final EIS/EIR Report of the DSWTP or an equivalent Transmission Project.

b) A final Interconnection Approval by the CA ISO for termination of the DSWTP or an equivalent transmission Project.at SCE's Devers Substation or any other Substation within the CA ISO-controlled grid.

c) Executed DSWTP Owner or similar Project Owner and CA ISO Interconnection Agreement.

d) Executed DSWTP Owner or similar Project Owner and Western Interconnection Agreement.

e) A Copy of the WECC/Watts Path Rating final Report.

f) A Copy of the CPCN permit, If a CPCN permit for the Transmission Project from the CPUC is involved,

g) A definite schedule from DSWTP Owner or similar Project Owner for commencing, and completing construction and commissioning of the DSWTP or similar Transmission Project.

ATTACHMENT D

BIOLOGICAL RESOURCES
Supplement

Testimony of Natasha Nelson and Elizabeth Hubert

INTRODUCTION

In order to mitigate impacts and to comply with LORS, the applicant has agreed to a zero liquid discharge (ZLD) to solids wastewater treatment system. Solids will be dried using a brine crystallizer. The applicant has requested to retain the evaporation ponds for use during periods of maintenance or emergency. Staff agrees to this method of wastewater treatment, but suggests Condition of Certification **BIO-12** to address the use of evaporation ponds for temporary disposal of wastewater, and to avoid significant impacts to wildlife.

The evaporation ponds would be lined with a black plastic liner and water would be allowed to evaporate unassisted. The primary water stream to the evaporation pond would be from the water treatment plant during maintenance and emergency upset conditions. During other times of year, only rainwater would accumulate in the ponds.

IMPACTS AND ANALYSIS

Temporary use of the evaporation ponds presents potential hazard to avian species and wildlife (CEC and WAPA 2005). In addition, the brown pelican, *Pelicanus occidentalis californicus* (federal endangered) and snowy plover, *Charadrius alexandrinus nivosus* (federal threatened, California Special Concern) have been recently found using areas in close proximity to the BEP I ponds (Conrad Jones, personal communication to Elizabeth Hubert, July 13 2005). The ponds could therefore present an additional hazard to protected species.

The water directed to the evaporation ponds would contain some levels of contaminants, including selenium, and would be extremely saline (>58,000 mg/L, BEP II 2002d, Table 7.13-7). Rainwater alone would not have any contaminants. Local summer storms produce rapid runoff from short-duration, high-intensity storms, while winter rains are gentle and are not expected to produce any significant runoff. Local rainstorms are not expected to produce enough volume to fill the ponds. However, after the first maintenance or emergency discharge to the pond, all rainwater that comes in contact with the waste will itself be considered contaminated

The applicant should be prepared to implement a hazing program to discourage wildlife exposure to the ponds starting with the first discharge event and any time contamination with waste discharges has occurred during the rest of the year. In the weeks prior to the nesting season, hazing should be implemented to discourage and prohibit nesting near the ponds.

In the future, the BEP II will experience either a planned or unexpected closure. To prevent exposure to chemicals and the spread of waste, the applicant should clean out any residue in the ponds should there be a closure of more than 2 months. Upon implementation of Condition of Certification **BIO-12**, only rainwater will accumulate and exposure to chemicals would be eliminated. Facility Closure Mitigation measures will need to be included in the Biological Resources Mitigation Implementation and Monitoring Plan prepared by the applicant under Condition of Certification **BIO-12**.

CONDITION OF CERTIFICATION

BIO-12 The project owner shall discharge brine to the evaporation ponds only in cases of cooling system maintenance or emergency. The project owner shall notify the CPM in case of any discharge. The project owner shall prepare an Evaporation Pond Mitigation and Monitoring Plan to ensure that any impacts from the discharge are mitigated. . If a substantial number of bird, wildlife, or protected species are found using the ponds, then remedial actions to reduce wildlife use to a less than significant level and to prevent nesting must be implemented. When such a discharge occurs to the evaporation pond, remedial measures shall be performed to discourage nesting and reduce bird and wildlife exposure to the ponds. The project owner shall submit records of all monitoring dates, data collected, and any corrective actions taken in the Evaporation Pond Monitoring Report. After any facility closure of more than two (2) months, the ponds shall be cleaned to minimize risk of contamination to wildlife. No clean-up of clean, untainted sediment that is windblown into the ponds is required.

The Evaporation Pond Mitigation and Monitoring Plan shall identify:

1. All biological resources to be impacted, avoided, or mitigated by evaporation pond use or closure;

2. A detailed description of all biological resources mitigation, monitoring, and compliance measures included in the Commission's Final Decision,

the Federal and State Endangered Species Acts, the California Environmental Quality Act, and the Migratory Bird Treaty Act;

3. A detailed description of methods to be used to avoid or discourage bird and wildlife use and to prevent nesting following any period of discharge;

4. Detailed description of remedial measures to be performed if initial methods do not meet specified condition;

5. The individual(s) who are responsible for monitoring and reporting;

6. Monitoring frequency, conditions, data collected, and reporting periods to be implemented following a discharge;

7. The proposed dates, duration, number of times per year, and volume for discharges to the evaporation ponds;

8. The cleaning schedule after any discharge to the ponds;

9. Reporting periods to be followed in the case of any unplanned or emergency discharge;

10. Methods to remove chemical residue in the ponds should a facility closure occur for more than two months; and

11. Reporting periods following a facility closure for more than two months.

Verification: At least thirty (30) days prior to the start of any site (or related facilities) mobilization, the project owner shall provide two copies of the Evaporation Pond Mitigation and Monitoring Plan and all supporting materials to the CPM for review and approval.

The CPM, in consultation with the CDFG, USFWS, and any other appropriate agencies, will determine the plan's acceptability within forty-five (45) days of receipt. Any modifications to the plan will follow the same approval and time periods as those for the BRMIMP (**BIO-5).**

The project owner shall submit an Evaporation Pond Monitoring Report to the CPM on a monthly basis. This monitoring shall continue for the at least the first three years of plant operation, and depending on the results, could be discontinued after consultation with the CPM if there is no evidence of significant wildlife exposure to the evaporation ponds.

The project owner shall submit records of all monitoring dates, data collected, and any corrective actions taken in the Evaporation Pond Monitoring Report.

The Report shall be sent to the Federal Aviation Administration, City of Blythe, Blythe Airport Staff, California Department of Fish and Game, U.S. Fish and Wildlife Service, and the CPM. The monitoring must continue until the applicant is given written approval from the CPM to stop.

During periods of sediment clean-up, the project owner shall submit a weekly progress report to the CPM.

REFERENCES

BEP II (Blythe Energy Project Phase II). 2002d. Revised Application for Certification for Blythe II. 07/03/2002 (tn: 26100)

BEP II (Blythe Energy Project Phase II). 2002f. Data Responses #1-102 (set #1). 09/30/2002 (tn: 26909)

CEC (California Energy Commission). 2005. Report of conversation between Elizabeth Hubert, CEC, and Conrad Jones, CDFG, re: evaporation ponds at Blythe site. 7/13/2005. rec'd 07/22/05.

CEC (California Energy Commission) and Western Area Power Administration. 2005. Final Staff Assessment. Blythe Energy Project Phase II. Publication # 700-2005-007. April 2005.

DECLARATION OF
Elizabeth Hubert

I, **Elizabeth Hubert,** declare as follows:

1. I am presently employed by the California Energy Commission in **the Environmental Protection Office** of the **Systems Assessments and Facilities Siting Division** as a **Planner I.**

2. A copy of my professional qualifications and experience is attached hereto and incorporated by reference herein.

3. I helped prepare the supplement to the **Biological Resources** section for the **Blythe Energy Project Phase II** based on my independent analysis of the application and supplements hereto, data from reliable documents and sources, and my professional experience and knowledge.

4. It is my professional opinion that the prepared testimony is valid and accurate with respect to the issue addressed therein.

5. I am personally familiar with the facts and conclusions related in the testimony and if called as a witness could testify competently thereto.

   I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Dated: July 26, 2005 Signed: Elizabeth Hubert

At: Sacramento, California

ELIZABETH HUBERT

PROFESSIONAL EXPERIENCE

BIOLOGIST *2005 to present*
Performed biological technical analyses and resource assessment for facility siting cases and planning studies. Worked as a member of interdisciplinary teams evaluating biological resources potentially affected by proposed power plants. Prepared testimony for hearings. Worked to ensure that existing power plants were in compliance with biological mitigation measures.

ASSOCIATE ECOLOGIST *Calif. Dept. of Parks and Recreation* *2001 to 2005*
Provided natural resource lead to a variety of State Park projects, including natural resource restoration, recreational trails, General Plans, and park facilities. Conducted research on sensitive resources, threatened and endangered species, and implemented scientific surveys and monitoring. Prepared environmental review, completed technical reports and identified necessary environmental reports and permits. Consulted with state and federal regulatory agencies to procure permits, Biological Opinions, and proposed mitigation and avoidance plans. Conducted resource inventories for State Park General Plans. Conducted research projects in park districts, emphasizing vegetation ecology and native grasslands. Prepared proposals, project agreements, technical reports, workplans and budgets. Prepared ecological components of restoration plans and mitigation plans. Conducted wetland delineations for projects with potential impacts under US Army Corps of Engineers and Coastal Commission jurisdiction. Implemented restoration on project sites.

ECOLOGIST *Calif. Dept. of Parks and Recreation* *2000 to 2001*
Performed ecological surveys and biological assessments in coastal parks. Conducted surveys for sensitive plant species and prepared technical reports. Coordinated research projects in grasslands. Delineated wetlands in coastal zone. Prepared management plans, and procedures for exotics removal. Wrote and supervised contracts and coordinated weed removal on park sites. Mapped and inventoried sites with noxious weeds. Provided lead to park aides and interns, hired seasonal staff. Worked with community groups to plan weed removal and planting events.

ECOLOGIST *Plumas N.F., Quincy, and Tahoe N.F., Nevada City, CA* *1996 to 2000*

Conducted field sampling and analysis for fire history studies; established permanent plots to measure forest health. Set up databases, and entered and analyzed data. Provided training to forest service staff. Coordinated and conducted research for comprehensive fire ecology literature review. Performed sensitive plant surveys to identify the presence and distribution of rare plant species in proposed projects. Developed impact analysis and mitigation recommendations. Prepared environmental documents and maps. Identified unknown plants, updated district records and maps. Prepared vegetation classification maps. Interpreted aerial photos and classified vegetation.

BOTANIST *Department of Water Resources.* *1993 to 1995*
Planned, researched, and conducted surveys for biological resource inventories. Set up and measured vegetation transects, analyzed data, wrote reports for environmental documents. Interpreted aerial photos; mapped, surveyed, and documented species and vegetative communities.

ADDITIONAL EXPERIENCE

- The Nature Conservancy: Grassland inventory and study plots
- Sequoia National Park: Biological resource inventory and fire history study
- Olympic National Park: Native vegetation restoration

EDUCATION

- **University of California, Santa Cruz** B.A. Environmental Studies (emphasis in Biology).
- **California State University, Chico.** Post-graduate study (Biology).

CONTINUING EDUCATION

- Wetland delineation refresher (Wetland Training Institute)
- Preparation of Biological Assessments and ESA Section 7 (USFWS)
- Habitat Conservation Plans (USFWS)
- ArcView GIS 8.3

GEA
Energy Technology Division

GEA Power Cooling Systems, Inc.

PAC SYSTEM®

Budgetary Information

Date:	5/22/03	Ref. No.:	2983
Company:	Pacific Group Electric Power		
Project:	Blythe II		
Contact:	Jim Schoonmaker		
Phone No.:	909-303-1707	Fax No.	909-303-1707

System Design Requirements	ACC 30° ITD	ACC 45° ITD	ACC 60° ITD	30% WET PAC
Steam Flow	1.02 E6 lbm/hr	1.02 E6 lbm/hr	1.02 E6 lbm/hr	1.02 E6 lbm/hr
Condenser Pressure	5.15" HgA	7.6" HgA	10.9" HgA	5.15" HgA
Steam Quality	98.7%	98.7%	98.7%	98.7%
Inlet Dry Bulb Temperature	105° F	105° F	105° F	105° F
Wet Bulb Temperature	N/A	N/A	N/A	68° F
Relative Humidity	N/A	N/A	N/A	14%
Site Elevation	390 ft	390 ft	390 ft	390 ft
ACC Backpressure at 65°F " HgA	2.15	3.10	4.3	N/A
PAC Backpressure/Makeup at 80°F DBT & 14% R.H. "HgA/gpm				2.94/590
PAC Backpressure/Makeup at 65°F DBT & 14% R.H. ."HgA/gpm				2.00/442

System Preliminary Design				
AIR COOLED CONDENSER				
No. of Bays	9	6	4	6
No. of Fan Modules/Bay	5	5	5	5
Fan Diameter	32 ft	32 ft	32 ft	32
Plot Area (W x L)	350 ft x 200 ft	225 ft x 190 ft	160 ft x 200 ft	255 ft x 196 ft
Height to Top of Steam Header	115 ft	100 ft	95 ft	100 ft
Total Fan Shaft Power	5,360 kW	3,560 kW	2,380 kW	3,900 kW
Motor Rating	200 hp	200 hp	200 hp	
Main Steam Duct Diameter	17 ft	15 ft	13 ft	15 ft
COOLING TOWER				
No. Cells				1
Fan Diameter				28 ft
Plot Area (W x L)				42 ft x 42 ft
Fan Shaft Power (Total)				90 kW
Motor Rating				150 hp
Circ. Water Flow Rate				12,700 gpm
Makeup (based on 2 cycles of concentration)				843 gpm

Budget Information				
Budget Price for PAC System® material and equipment delivered to site.	$17,500,000	$11,500,000	$9,000,000	$14,000,000

Remarks

The quoted price for the proposed PAC System® is per the attached Scope of Supply
The quoted price for the proposed ACC is per the attached Scope of Supply

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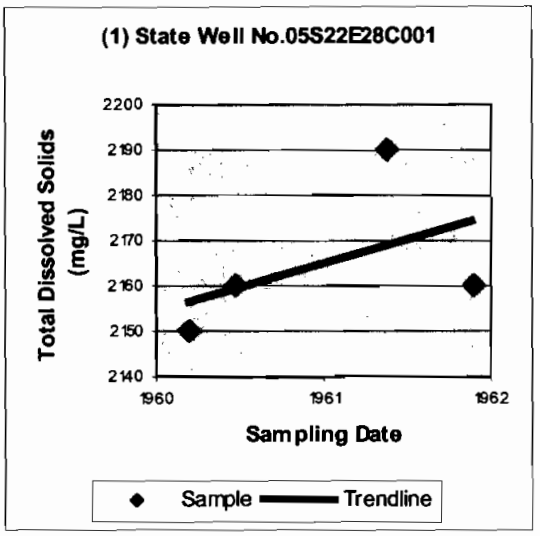
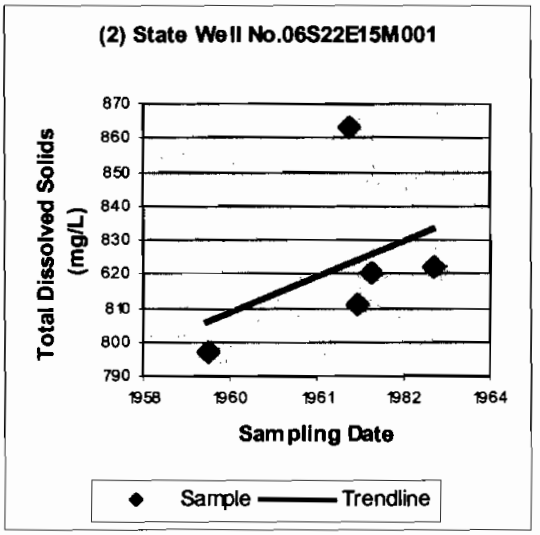
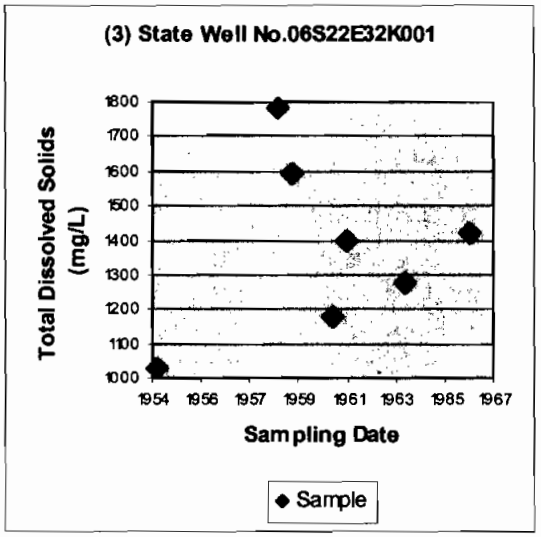
SOIL AND WATER RESOURCES – BLYTHE ENERGY PROJECT II (02-AFC-01)
Palo Verde Mesa - Groundwater Quality Sampling



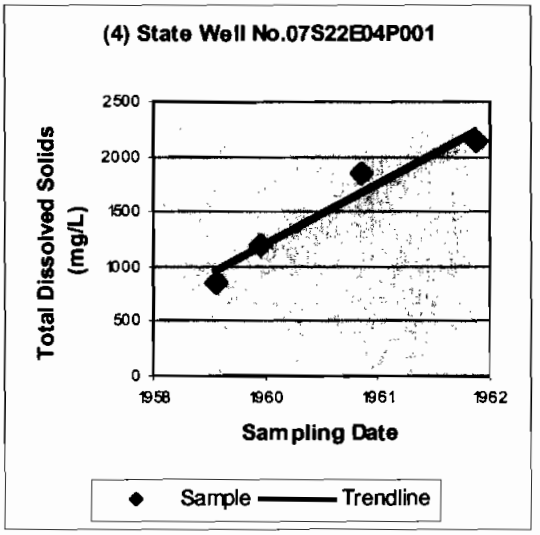
Well Depth = 601 feet below land surface (BLS) (116 feet below mean sea level (MSL)).



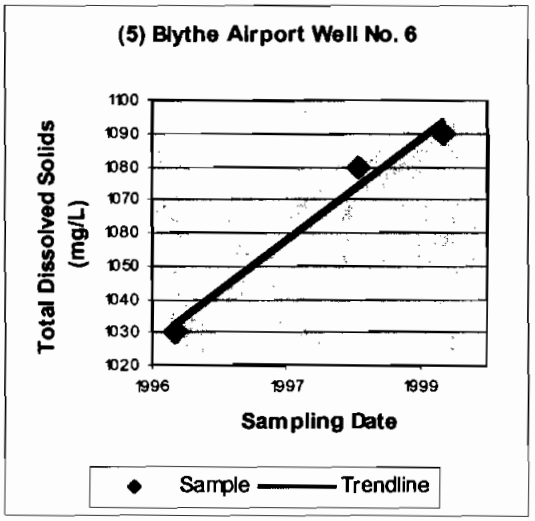
Well Depth = 315 feet BLS (81 feet above MSL).



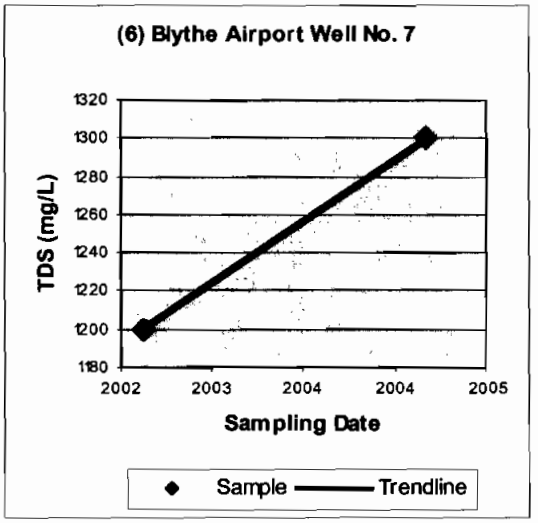
Well Depth = 464 feet BLS (101 feet below MSL).



Well Depth = 136 feet BLS (174 feet above MSL)

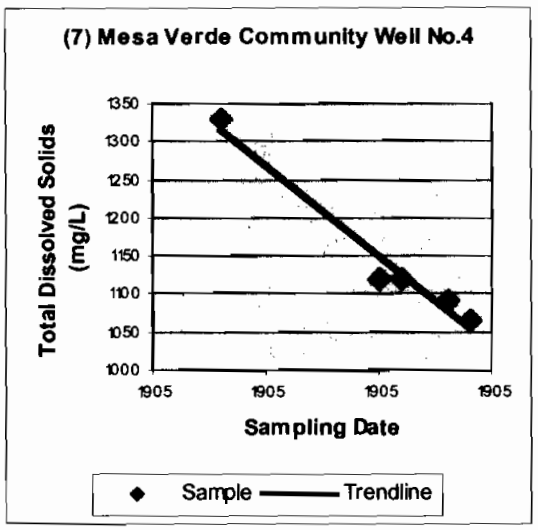


Well Depth = Reported shallower than Airport Well No.7 (Edwards, City of Blythe, ROC 7/8/2005)

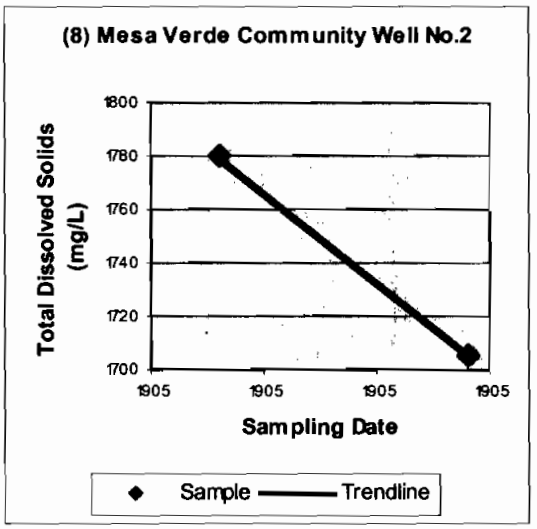


Well Depth = 500 feet BLS (approx. 140 feet below MSL).

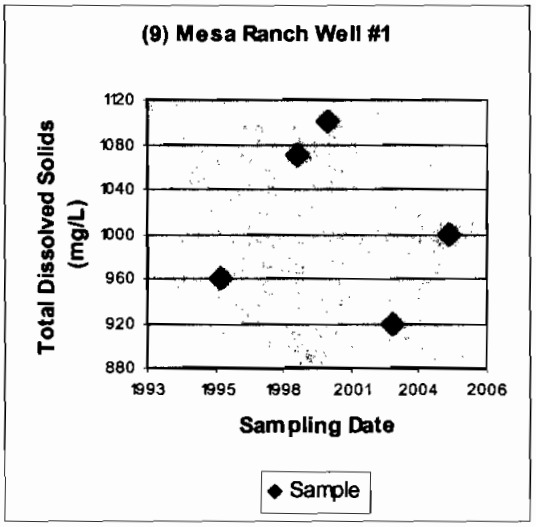
Palo Verde Mesa - Groundwater Quality Sampling



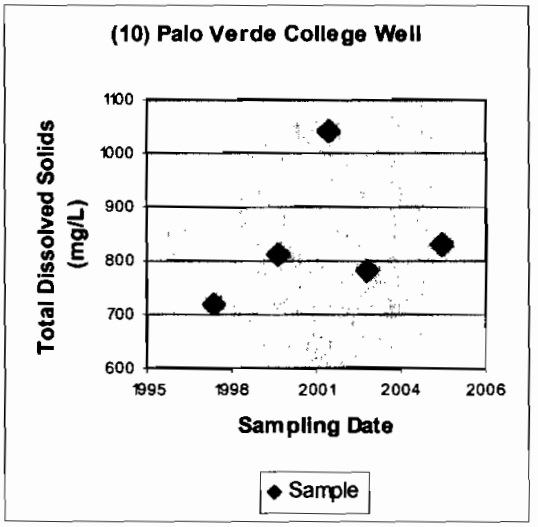
Well Depth = 750 feet BLS.



Well Depth = 400 feet BLS.



Well Depth = 480 feet BLS.



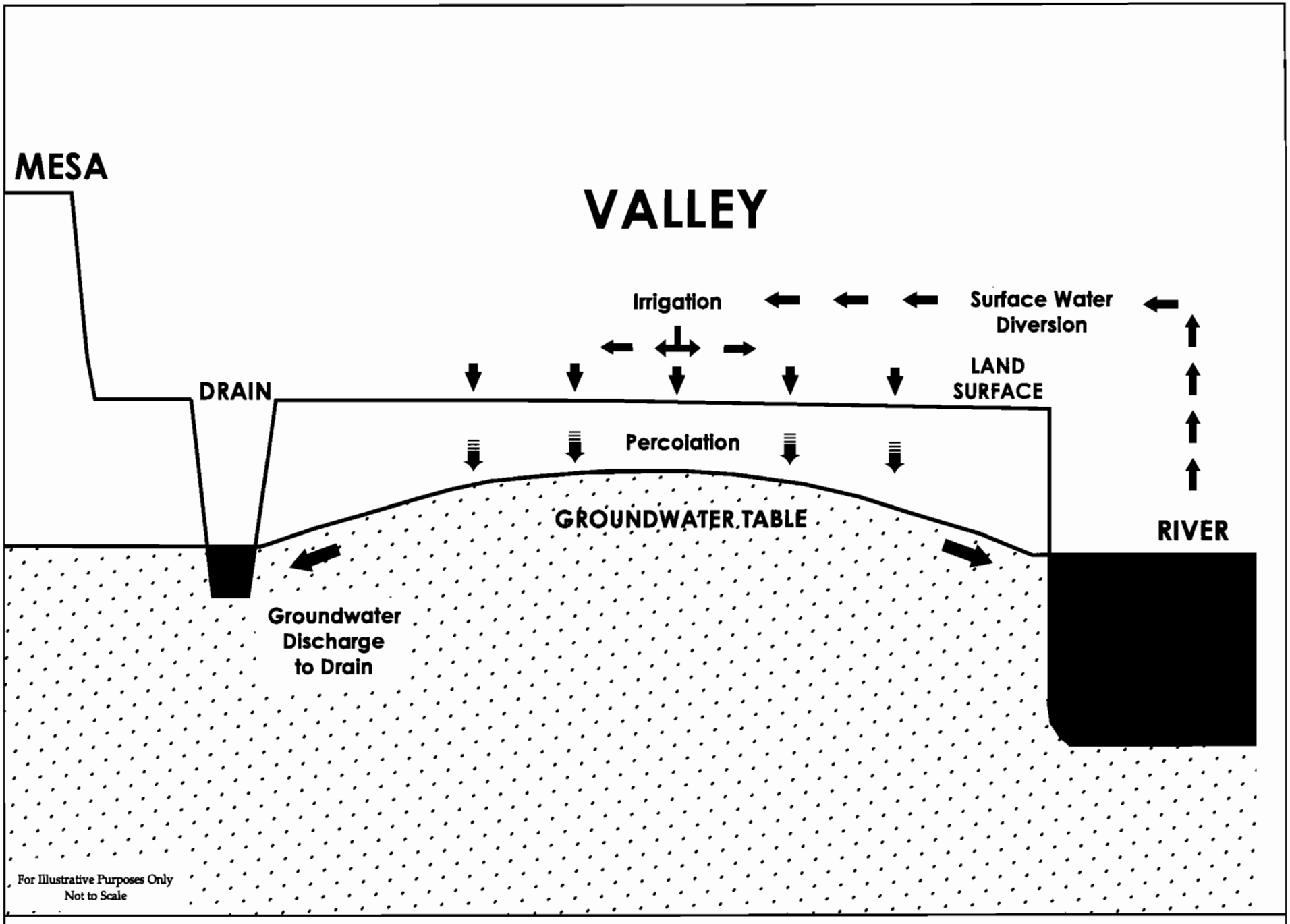
Well Depth = 480 feet BLS.

Sources:
City of Blythe. Record of Conversation, City of Blythe, Department of Public Works: Mark Edwards, Energy Commission: Linda Bond, July 8, 2005, Subject: TDS data for the Blythe Airport and the Mesa Ranch wells. (Plots 5, 6, 9 and 10)

Riverside County. Facsimile, Riverside County, County Service Area 122: James Teater, Energy Commission: Linda Bond, July 11, 2005, Subject: TDS Well Construction and Groundwater Sampling Data for Mesa Verde Well #4 and #2. p7. (Plots 7 and 8)

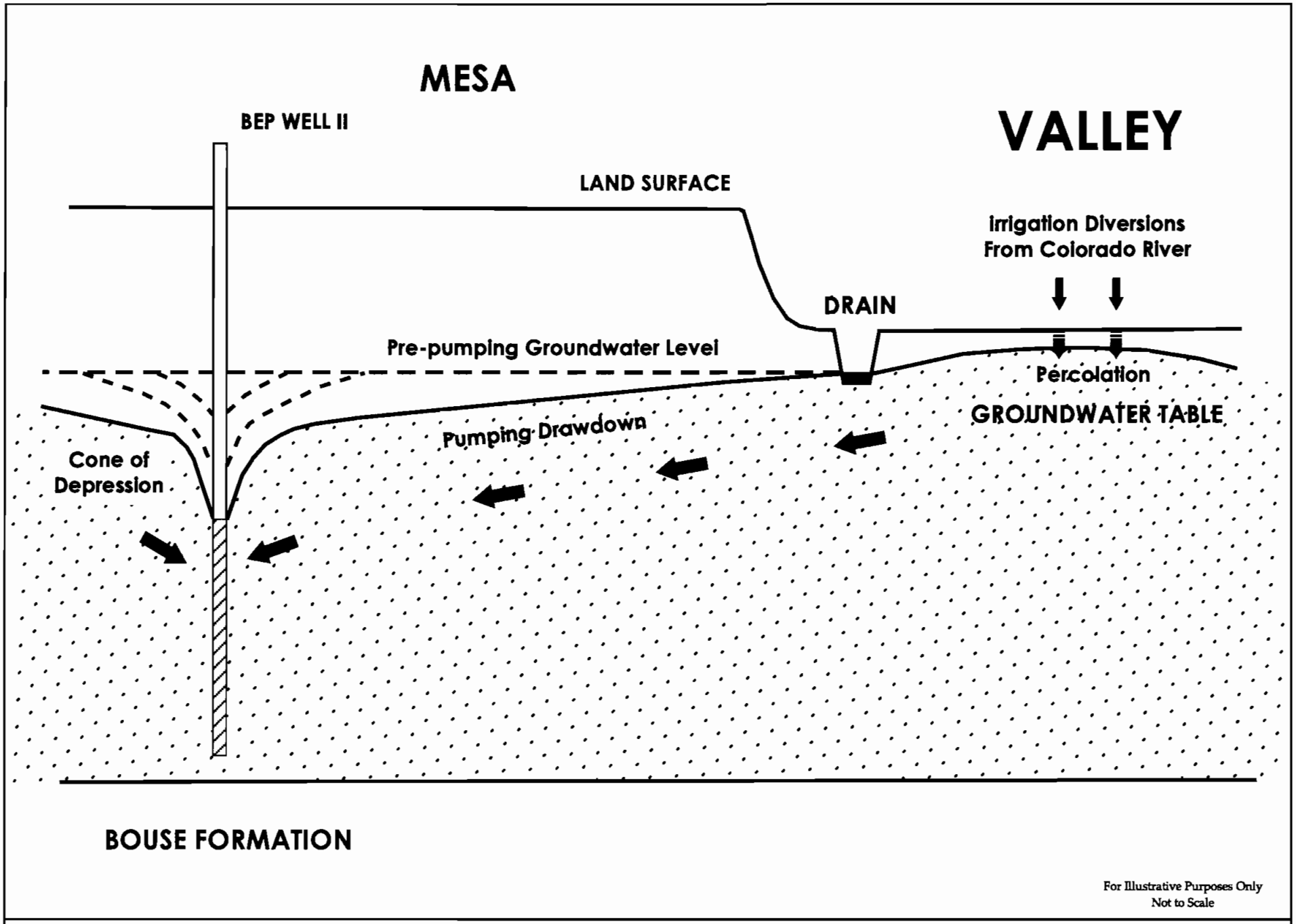
USGS. 2005. Water Chemical and physical data for streams, lakes, springs, and wells. (NWISWeb, http://nwis.waterdata.usgs.gov) (Plots 1 through 4)

Abbreviations:
BLS – below land surface
MSL – mean sea level



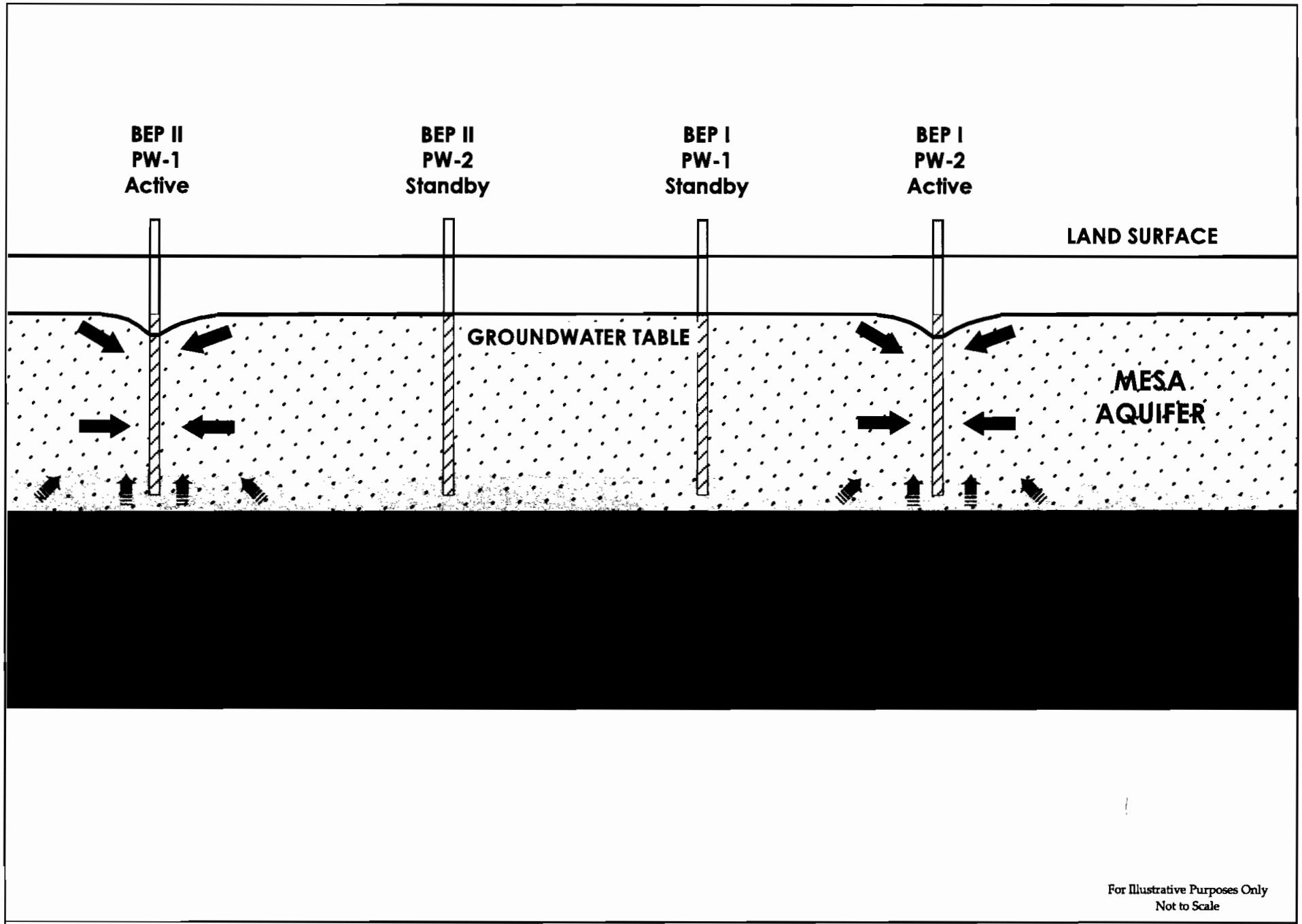
BLYTHE ENERGY PROJECT PHASE II

HYDROLOGY OF PALO VERDE VALLEY



BLYTHE ENERGY PROJECT PHASE II

HYDROLOGY OF GROUNDWATER PUMPING IN THE PALO VERDE MESA



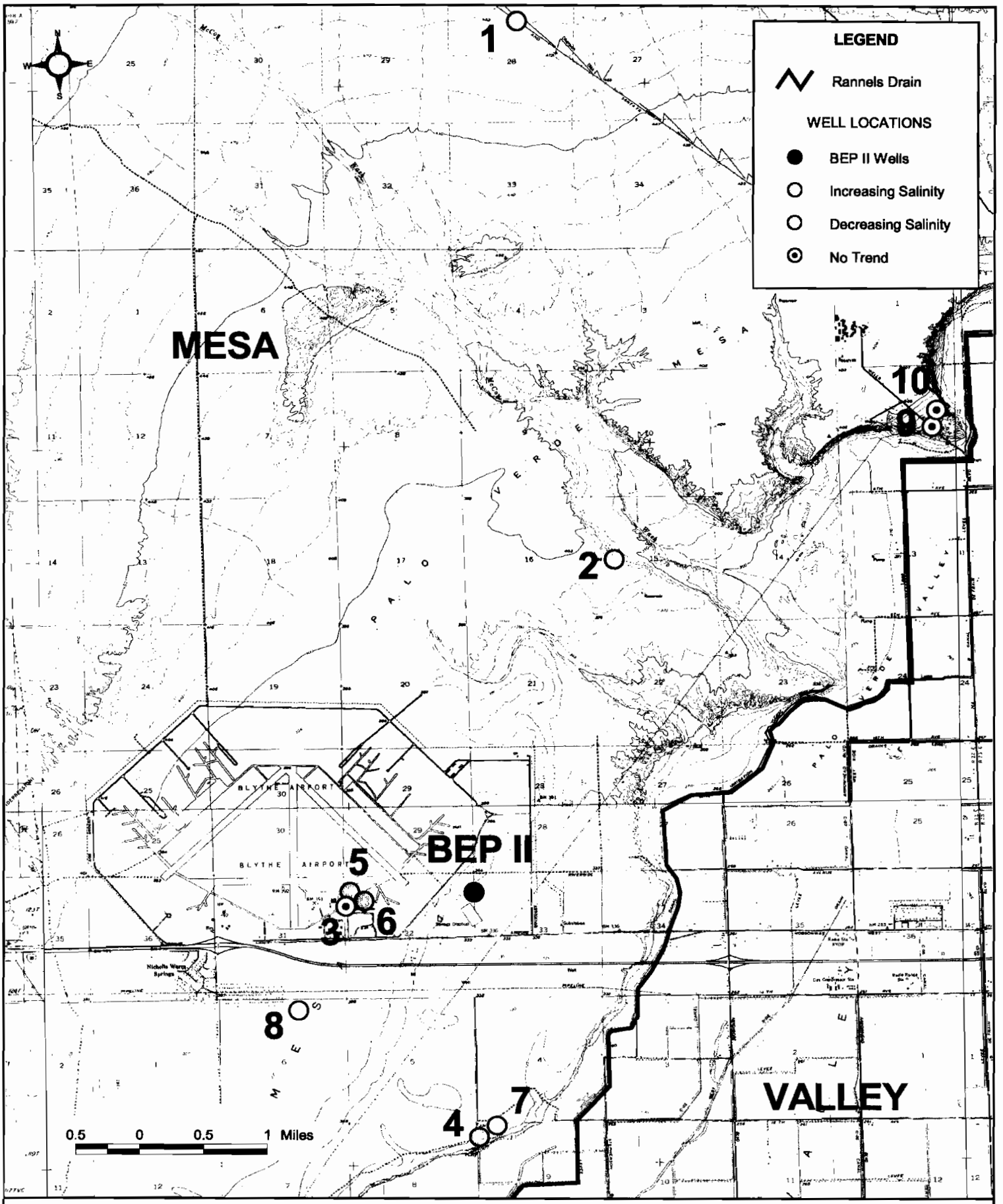
BLYTHE ENERGY PROJECT
PHASE II

UPWELLING OF SALINITY

SOIL AND WATER RESOURCES – BLYTHE ENERGY PROJECT II (02-AFC-01)
Palo Verde Valley - Water Quality Sampling in PVID Surface Drains

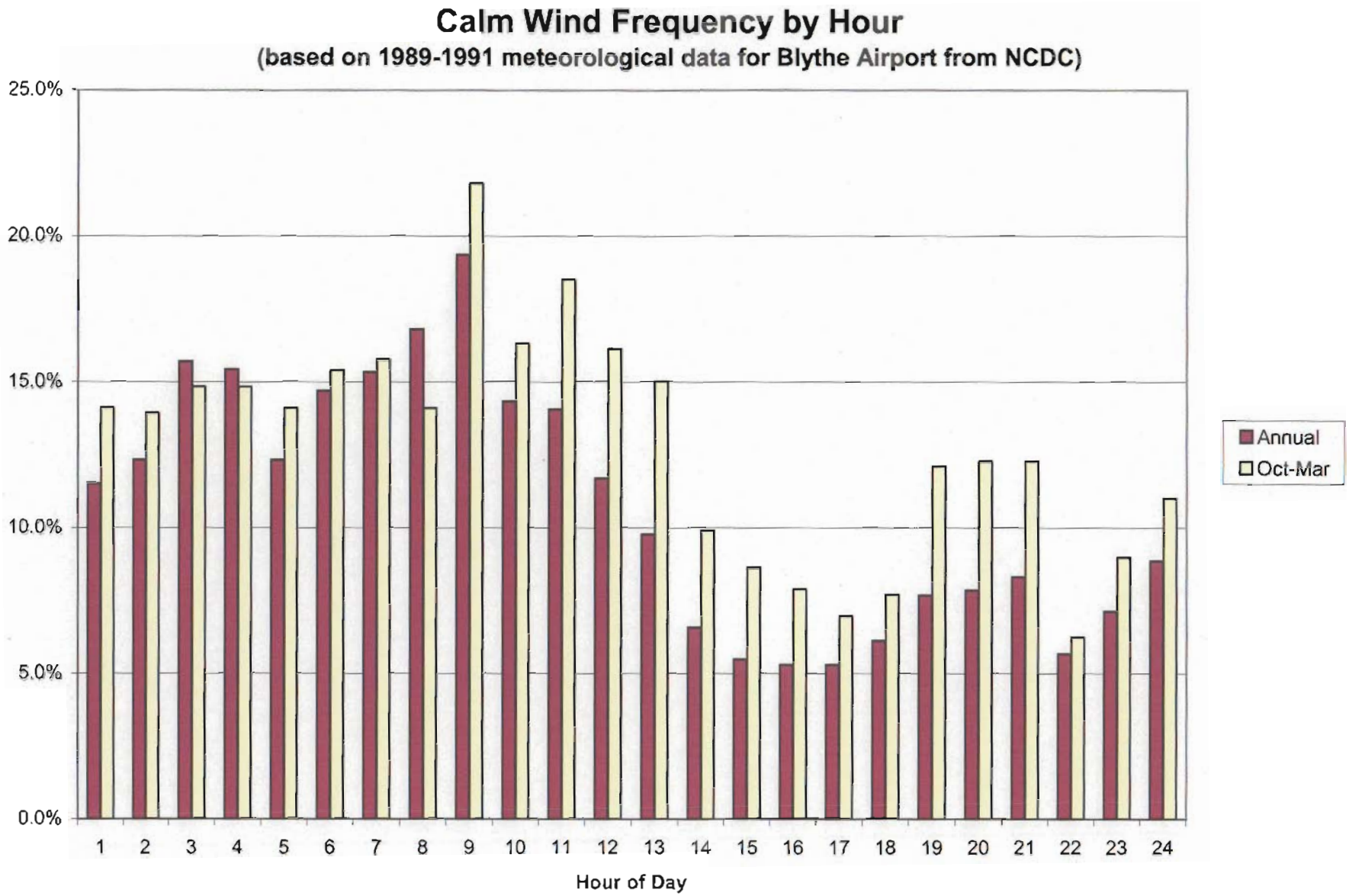
	TOTAL DISSOLVED SOLIDS (mg/l)	
DRAIN	UCAE[a]	BOOKMAN-EDMONSTON[b]
Brown	1580	1540
Central	1440	1350
East Side	1120	950
Hodges	3500	2880
Lovekin	1330	1030
Lower Borrow Pit	1450	1420
Palo Verde	2640	2160
Rannells	1830	1920
South End	2370	2120
Township[c]	1210	1180
West Side	1500	1480

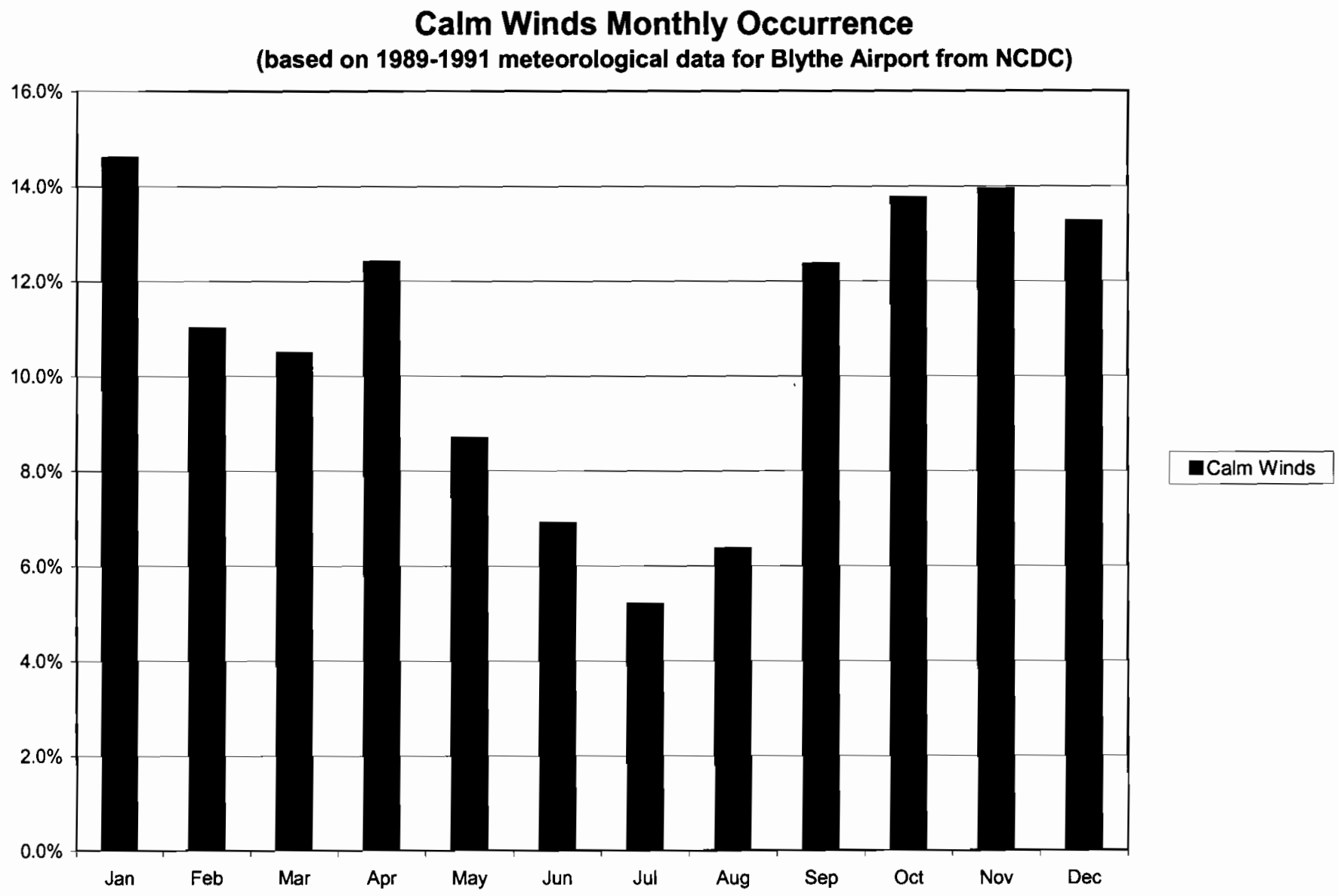
(a) Average of University of California Agricultural Extension Service Samples from 1967 to 1971.
(b) Sampled by Bookman-Edmonston in November 1975.
(c) Includes water from East Side, Central and Lovekin.
Source: Bookman-Edmonston Engineering, Inc. 1976. Reduction of Salt Loading to the Colorado River from Palo Verde Irrigation District: Prepared by Bookman-Edmonston Engineering, Inc. for the United States Bureau of Reclamation, 75 p., Table 2. Comparison of Salinity of Water in Surface Drains.

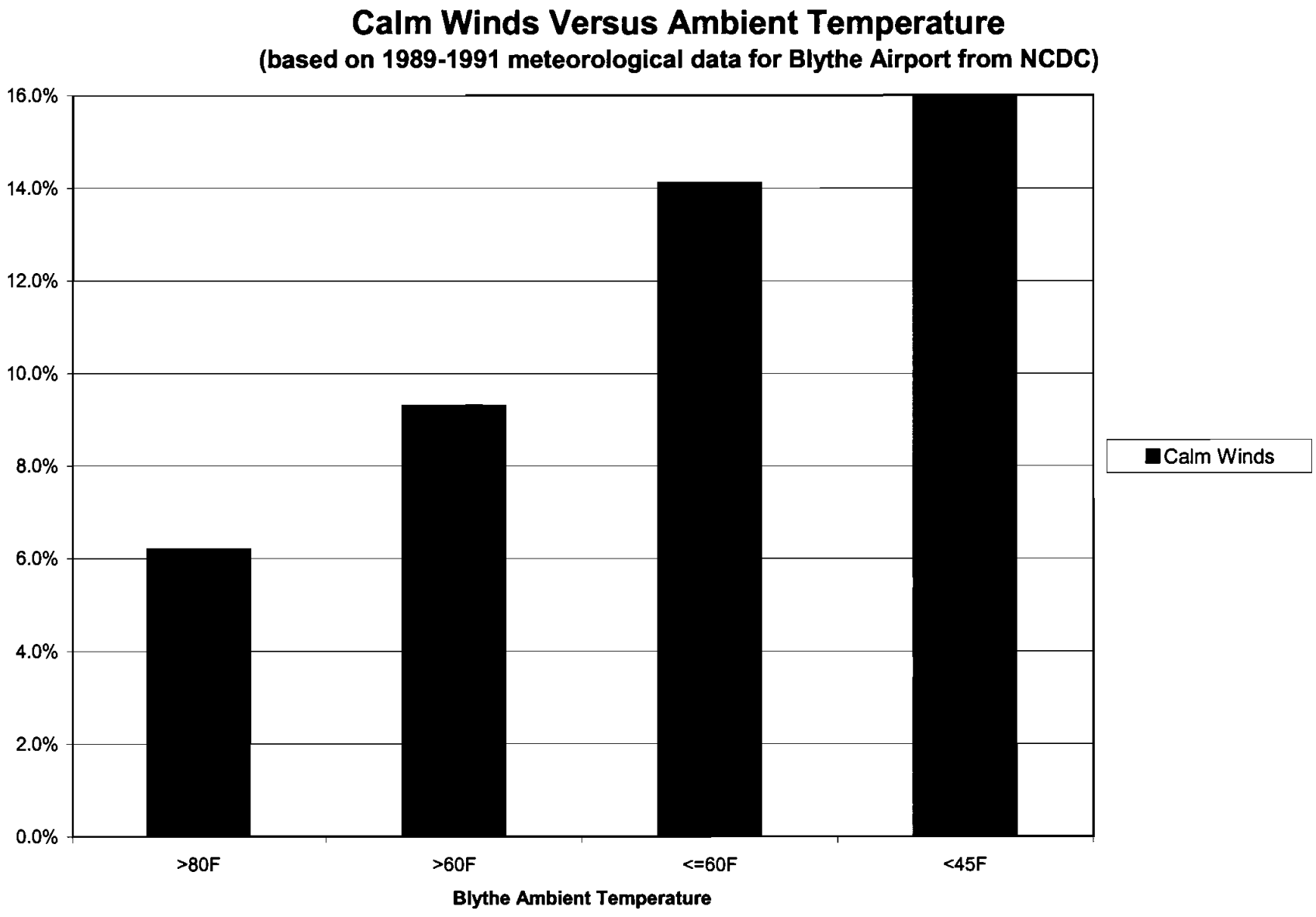


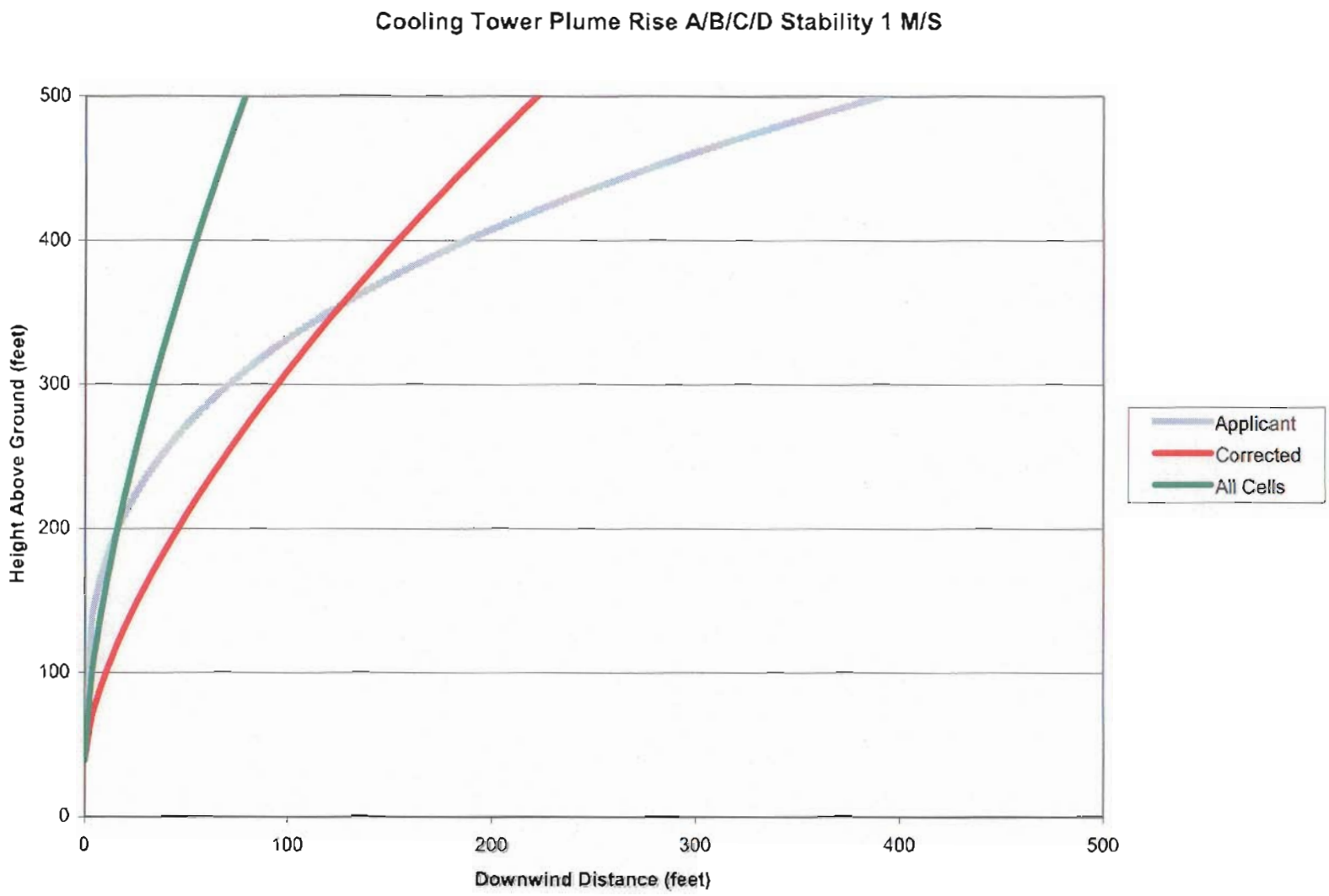
BLYTHE ENERGY PROJECT PHASE II

PALO VERDE MESA WELLS SAMPLED FOR SALINITY OVER TIME

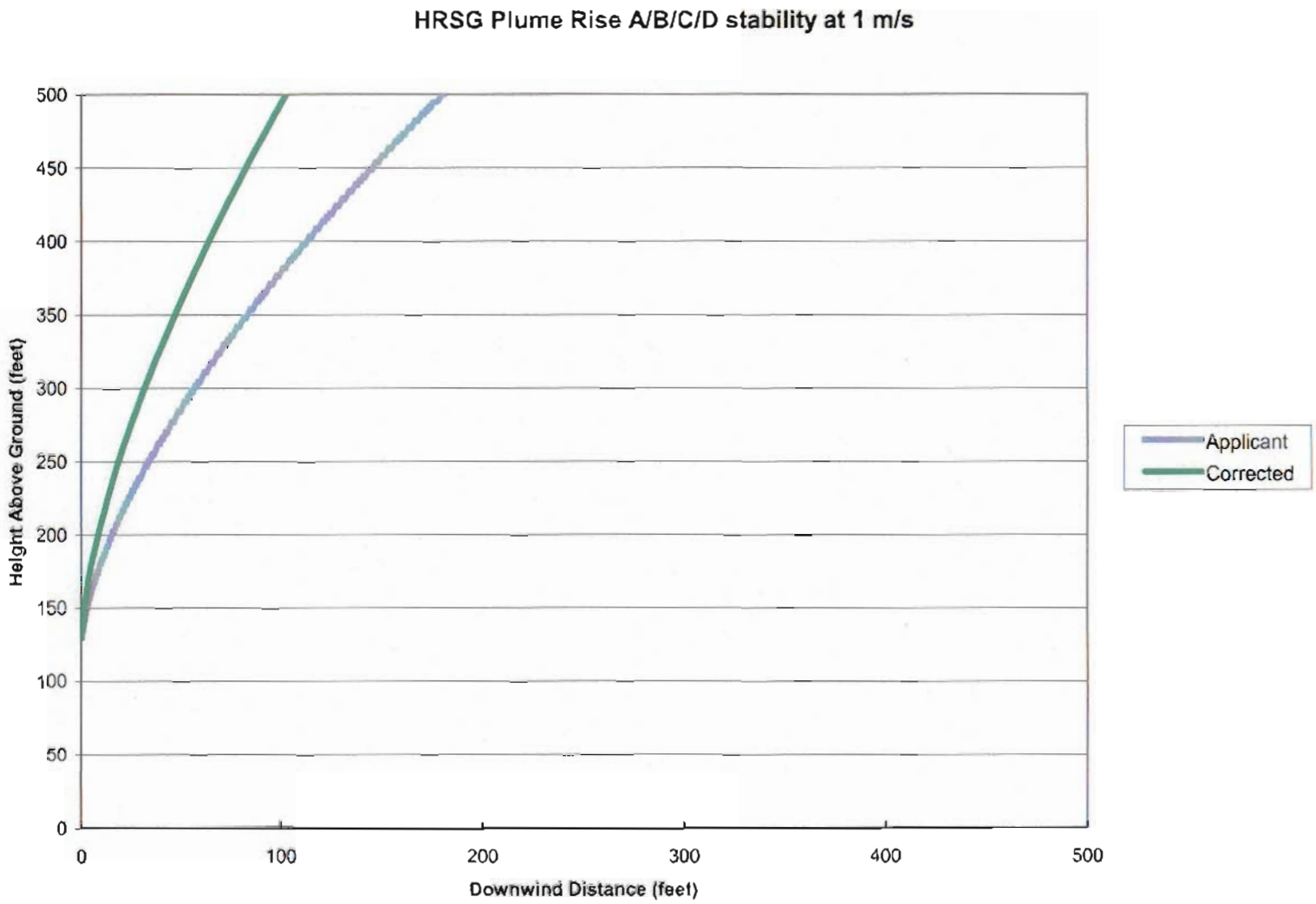

Calm Wind Frequency by Hour
(based on 1989-1991 meteorological data for Blythe Airport from NCDC)
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day
Annual
Oct-Mar


Calm Winds Monthly Occurrence
(based on 1989-1991 meteorological data for Blythe Airport from NCDC)
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Calm Winds


Calm Winds Versus Ambient Temperature
(based on 1989-1991 meteorological data for Blythe Airport from NCDC)
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
>80F
>60F
<=60F
<45F
Blythe Ambient Temperature
Calm Winds

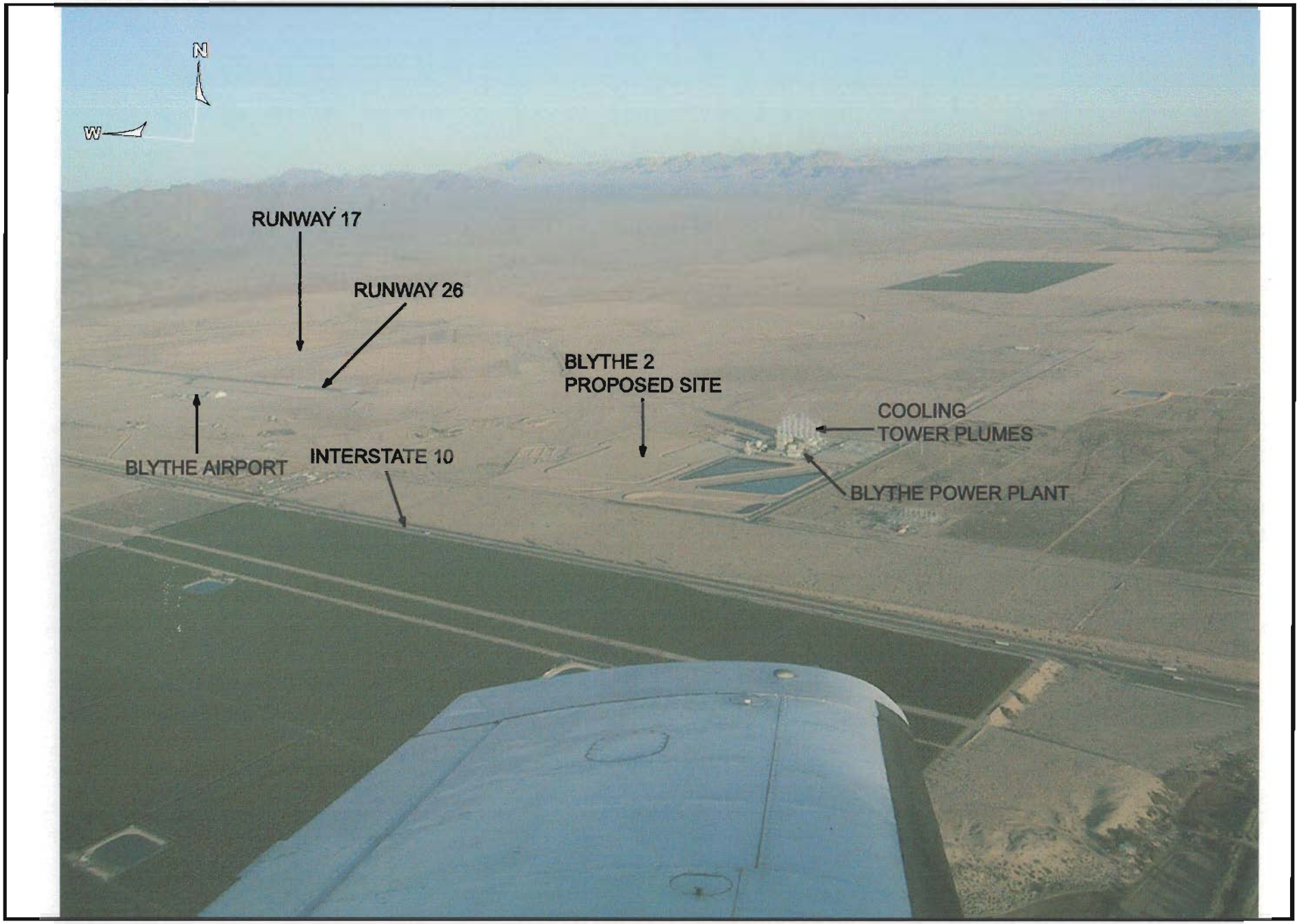


This figure provides cooling tower ISCST3 plume rise data corrected for worst cold weather case ambient conditions (Corrected) for a single cell exhaust and for the combined cooling tower as a single equivalent diameter exhaust (All Cells), the two of which should bound the ISCST3 predicted plume rise. The corrected data assumes a worst-case ambient temperature of 30°F rather than the 85°F used by the applicant, and corrects the cooling tower design specifications using the applicant's air quality modeling analysis. The plume rise for the cold weather case is significantly less affected by the wind than the case shown in the applicant's testimony.



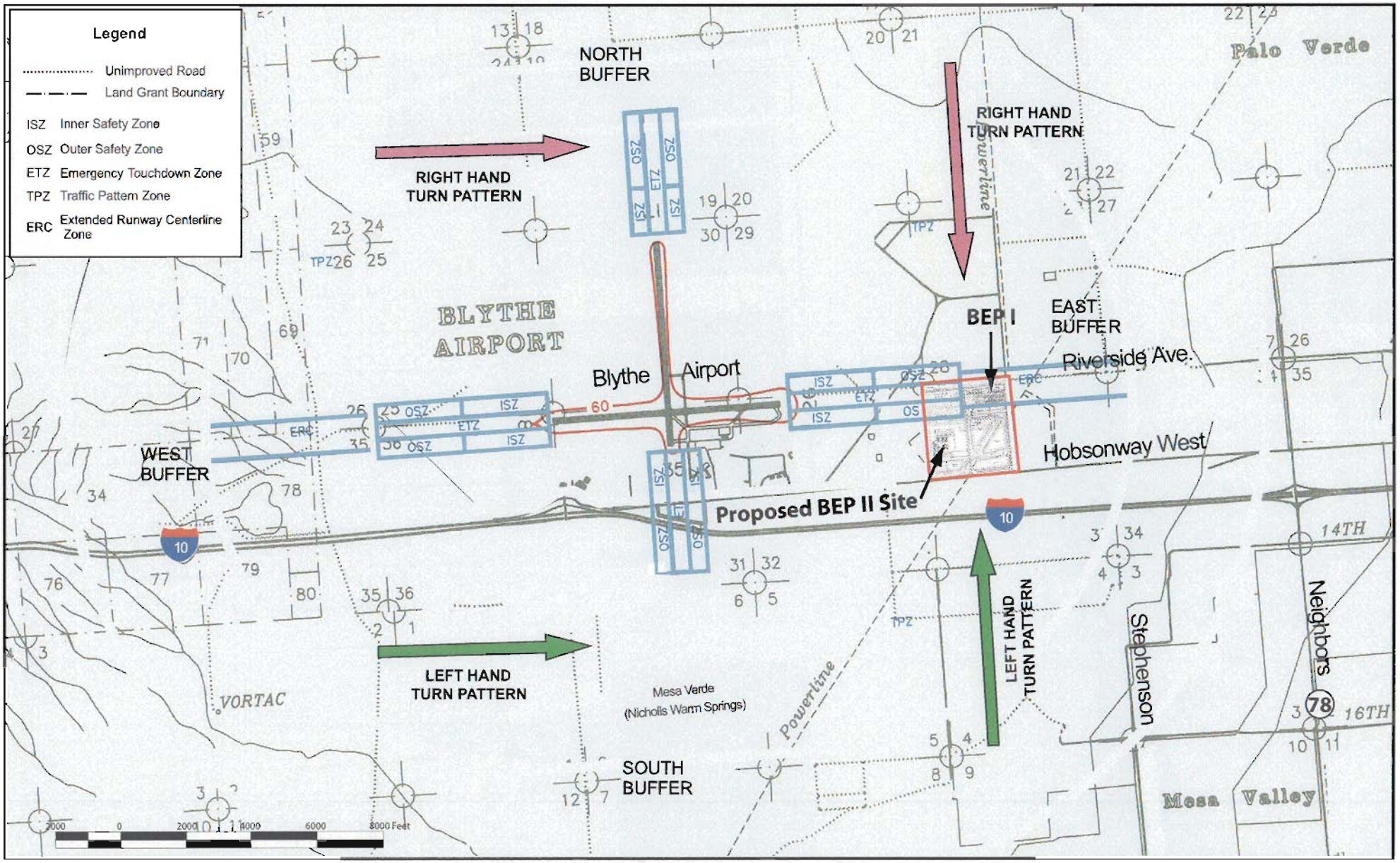
This figure presents a corrected ISCST3 predicted HRSG plume rise curve that uses corrected exhaust temperatures and flows during a worst case cold weather condition (30°F vs. the applicant's testimony value of 85°F), and the uncorrected applicant curve. The corrections use proper full load exhaust flow and temperature data from the applicant's air quality modeling analysis.

Blythe Energy Power Plant and Blythe Energy Project - Phase 2 Proposed Site - 3,000 feet above ground level



CALIFORNIA ENERGY COMMISSION, SYSTEMS ASSESMENT & FACILITIES SITING DIVISION
SOURCE: Photo taken by Commission Aviation Consultant Bill Arnold on November 3, 2004

Blythe Energy Project Phase II - Blythe Airport Safety Zones



CALIFORNIA ENERGY COMMISSION, SYSTEMS ASSESMENT & FACILITIES SITING DIVISION, MARCH 2005

SOURCE: BEP II 2002a - Figure 7.2-2, BEP II 2002b - Figure 36-1, Coffman - Exhibit 7a

Australian Government
Civil Aviation Safety Authority

Advisory Circular

AC 139-05(0) JUNE 2004

GUIDELINES FOR CONDUCTING PLUME RISE ASSESSMENTS

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1. REFERENCES

- Manual of Standards Part 139 – Aerodromes, Chapter 10

2. PURPOSE

2.1 The purpose of this Advisory Circular (AC) is to provide guidance to aerodrome operators and persons involved in the design, construction and operation of facilities with exhaust plumes about the information required to assess the potential hazard from a plume rise to aircraft operations.

2.2 CASA has identified that there is a need to assess the potential hazards to aviation because the vertical velocity from gas efflux may cause airframe damage and/or affect the handling characteristics of an aircraft in flight.

2.3 The stability of an aircraft is especially critical during periods of high pilot workload, such as when the aircraft is being manoeuvred at low altitudes with flaps extended and/or gear down. Typically, this includes the initial take-off climb and the approach to land - when the aircraft is in the vicinity of an aerodrome.

2.4 In some cases, the high efflux temperature or velocity may cause air disturbance at higher altitudes. In this case, CASA also requires an assessment of the potential for the exhaust plume to affect the safe handling of aircraft in other phases of flight.

Advisory Circulars are intended to provide recommendations and guidance to illustrate a means but not necessarily the only means of complying with the Regulations, or to explain certain regulatory requirements by providing interpretative and explanatory material.

Where an AC is referred to in a 'Note' below the regulation, the AC remains as guidance material.

ACs should always be read in conjunction with the referenced regulations

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DATE JUL 27 2005
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3. STATUS OF THIS AC

3.1 This is the first AC on the subject of plume rise assessments.

4. BACKGROUND

4.1 Exhaust plumes can originate from any number of sources; chimneys; elevated smoke stacks at power generating stations; smelters; combustion sources; a flare created by an instantaneous release from pressurised gas systems all create exhaust plumes to one degree or another.

4.2 Aviation authorities have established that an exhaust plume with a vertical gust in excess of 4.3 metres/second (m/s) may cause damage to an aircraft airframe, or upset an aircraft when flying at low levels.

4.3 Low level flying operations are typically conducted during:

- approach, landing and take-off
- specialist flying activities such as, crop dusting, cattle mustering, pipeline inspection, power line inspections, fire-fighting, etc
- search and rescue operations
- military low-level manoeuvres

4.4 While approach, landing and take-off are normally conducted in the vicinity of an aerodrome, the other low level operations can be conducted anywhere across the country.

4.5 The risk posed by an exhaust plume to an aircraft during low level flight can be managed or reduced if information is available to pilots so that they can avoid the area of likely air disturbance.

4.6 As a result of this, CASA requires the proponent of a facility with an exhaust plume, which has an average vertical velocity exceeding the limiting value (4.3 m/s at the aerodrome Obstacle Limitation Surface (OLS) or at 110 metres above ground level anywhere else) to be assessed for the potential hazard to aircraft operations.

4.7 The stack itself may also need to be assessed and reported as a "tall structure" in accordance with the guidelines provided in AC 139-08.

5. THE ROLE OF THE PROPONENT

5.1 The proponent of a facility that creates an exhaust plume has a legal responsibility and a duty of care to provide details of the facility to CASA so that CASA and aerodrome owners can assess the potential hazards to aircraft safety.

5.2 Proponents of a facility to be located within 15 kilometres of an aerodrome, are to consult the aerodrome operator if that facility includes a combustion source which generates an exhaust plume which has a vertical velocity greater than 4.3 m/s at the height of the OLS.

5.3 Should an aircraft accident or incident be attributed to air turbulence created by a plume - the role of persons and/or organisations associated with the construction and operation of the facility would ultimately be examined by the courts.

5.4 In areas remote from an aerodrome, CASR Part 139 requires the proponent of such facilities to notify CASA if the exhaust plume would have a vertical velocity greater than 4.3 m/s at a height of 110 metres or more AGL.

6. THE ROLE OF THE AERODROME OPERATOR

6.1 CASR Part 139 requires aerodrome operators to notify CASA of any existing or potential obstacles, i.e. any object that infringes or will infringe the aerodrome OLS. This may include the area within 15 kilometres of the aerodrome.

6.2 The "obstacle" referred to in CASR Part 139 does not necessarily have to be a solid object like a building or stack. It can include gaseous efflux which is capable of physical definition or measurement.

6.3 For the purposes of CASR Part 139, the hazardous gaseous efflux is defined as the vertical and horizontal limits of the exhaust plume at which the average vertical velocity reduces to a value of 4.3 m/s.

6.4 Just like a physical penetration of the OLS, the aerodrome operator is required to notify CASA of the details of the exhaust plume, so that CASA can determine if it should be classified as a "hazardous object" under CASR Part 139.

6.5 In the vicinity of major capital city airports (and other leased Federal Airports) the *Airports (Protection of Airspace) Regulations* also apply. Under these regulations, the aerodrome operator has an obligation to notify the Department of Transport and Regional Services (DOTARS) of any potential infringement of the prescribed airspace established for the aerodrome. DOTARS has the power to prohibit, or limit, the erection of a facility with an exhaust plume, which has an average vertical velocity greater than 4.3 m/s at the lower limit of the prescribed airspace.

7. THE ROLE OF THE CIVIL AVIATION SAFETY AUTHORITY (CASA)

7.1 Where there is a potential to impact on aircraft safety, both structural and non-structural elements of a proposal will need to be assessed. This may happen concurrently, or may be undertaken separately where it is likely that the structural elmenent would be critical in it's own right.

7.2 When a proposed facility with potential efflux discharges is assessed for conformance under an aerodrome OLS or PANS-OPS surface, and the airspace is likely to be penetrated by the structure itself, technical details of the discharge rates need not be submitted with the initial notification to CASA and the aerodrome operator.

7.3 On the other hand, when a proposed facility is located under the OLS and PANS-OPS surfaces but its efflux discharges into the OLS or and PANS-OPS surfaces, then technical details of discharge rates etc. should be submitted in conjunction with height details to CASA and the aerodrome operator.

7.4 In areas remote from an aerodrome, when notified of a proposal that has an exhaust plume with a vertical velocity greater than 4.3 m/s **or** at a height of 110 metres or more above ground level, CASA will determine the effect on aircraft safety. In this case, CASA will assess whether or not the exhaust plume should be classified as a hazardous object under CASR Part 139.

7.5 In the case of a solid object, CASR Part 139 provides for its marking and/or lighting so that its shape is delineated and made visible to pilots operating at night, or in reduced

visibility conditions. Since this is not feasible for an exhaust plume, CASA will be obliged to consider alternative measures to make sure that pilots are unlikely to encounter air turbulence resulting from vertical plume velocities in excess of 4.3 m/s. Such measures might include:

- amendment to an existing instrument approach and/or departure procedure
- declaration of a Danger Area centred on the source of the plume

7.6 In determining the need for a Danger Area, CASA will consider the severity and frequency of the risk posed to an aircraft which might fly through the plume. This assessment requires plume rise data to be provided as a probability distribution for the height and lateral limit of the critical vertical velocity.

7.7 Since plume rise and lateral dispersion are highly dependent on crosswind and the temperature differential between the plume and ambient air, this assessment requires the use of site specific metrological data throughout the full height of the plume.

8. APPLICATION FOR APPROVALS

8.1 The proponent of a development that will generate an exhaust plume, which may pose a risk to aircraft operations, must provide CASA with sufficient details to make a hazard assessment. The "Application for an Operational Assessment of a Proposed Plume Rise" form at Attachment B can be used for this purpose.

8.2 To date, proponents of these developments have used a number of models to estimate the likely rise and lateral dispersion of the exhaust plume. In the absence of reliable meteorological data, plume rise has often been assessed in still air conditions. Whilst this represents a worst case scenario, the probability of this occurrence in actual weather conditions at the development site is usually quite low.

8.3 Lateral dispersion may similarly have been misrepresented, because these models assume that wind conditions are constant with height. This has often led to an overly conservative estimate of aviation impacts, and in some cases unnecessary restrictions on aircraft operations or even the refusal of the proposal.

8.4 Earlier guidelines set by CASA required consideration of oxygen content and temperature gradient within the plume, however this is no longer the case. Plume assessments to date have demonstrated that temperature and oxygen content quickly regain their ambient levels well before the vertical velocity is reduced to the 4.3 m/s vertical gust threshold.

8.5 This AC sets out the minimum requirements, established by CASA, for the analysis of the vertical rise and dispersion of hot buoyant plumes, and the data presentation requirements for the hazard assessment of the risk posed to aircraft operations.

8.6 Exhaust plumes from minor industries would not normally require the sophistication of "The Air Pollution Model" analysis, as their plumes tend to dissipate within 10 m above the stack height. However, exhaust stacks located within the take-off and approach areas of an aerodrome, and in close proximity to a runway, would still need to be assessed. In this case, standard plume rise equations should be adequate.

9. THE USE OF DIFFERENT PLUME MODELS

9.1 Environmental regulatory authorities routinely require the modelling of plume dispersion from industrial sources as the means of predicting ground level concentrations

of air pollutants. A range of software applications, such as "AUSPLUME" (Environment Protection Authority of Victoria) and the "ISC3" (Environment Protection Authority of the USA), have been developed for this purpose. These are relatively simple steady-state mathematical simulations, known as Gaussian plume models.

9.2 These air dispersion models typically incorporate a plume rise module, which calculates the height to which pollutants rise due to momentum and buoyancy. They also include a dispersion model which estimates how they spread as a function of wind speed and atmospheric stability.

9.3 These same models can provide the basis for estimating the potential effects on aviation, by predicting values of vertical velocity as a function of height and lateral dispersion of the plume.

9.4 These models use either ground level or near-surface wind speed data from sources such as an anemometer. In their simplest forms, they assume that wind speed remains constant with height, and there is no wind shear. A "worst case" **plume rise** is typically evaluated by assuming calm conditions while the "worst case" **lateral dispersion** is calculated by assuming that the maximum surface, or near-surface level, wind is constant throughout the height of the plume.

9.5 In reality wind speed and direction can vary considerably with height. As a result, some models attempt to simulate this situation by predicting increasing wind speeds with height, based on a simple power law relationship.

9.6 Since stack plumes may disperse at hundreds of metres above ground level, realistic modelling requires meaningful wind and temperature data throughout the height of the plume.

9.7 More advanced numerical models are now available that enable better representation of atmospheric processes using three-dimensional meteorological fields. Even so, their use has been limited because of the need for site specific meteorological observations.

9.8 The Air Pollution Model (TAPM) is a combined predictive meteorological module, and plume dispersion module, which provides a better alternative for realistic estimates of plume rise and lateral dispersion/displacement. This combination provides a three dimensional grid type simulation model which is most suited in estimating the frequencies of occurrences.

9.9 Where a stack is proposed in the vicinity of an aerodrome, additional meteorological data such as cloud cover and visibility can also assist in determining separate aviation impacts in visual or instrument meteorological conditions. This too can be provided by TAPM.

9.10 TAPM, run in **meteorology mode**, reliably simulates the complex three dimensional behaviour of the atmosphere and predicts site-specific hourly-averaged meteorological data. In the **plume rise mode**, TAPM analyses plume behaviour in the meteorological conditions which were likely to have been experienced at the site.

9.11 CASA considers that TAPM provides the ability for realistic plume modelling where there is no reliable meteorological data available from measurements/observations.

9.12 TAPM software was developed by the CSIRO in 1999 and TAPM v2.0 was released in April 2002. It predicts three-dimensional meteorology and air pollution concentrations.

9.13 TAPM solves approximations of the fundamental equations of the atmosphere to predict meteorology and pollutant concentrations, eliminating the need to have site-specific

meteorological observations. Plume behaviour is in turn assessed by reference to the predicted meteorology.

9.14 The Plume Rise Module is used to account for plume momentum and buoyancy effects for point sources. This has been validated against the most commonly used mathematical equations for hot buoyant plumes in both calm and windy conditions. Plume rise is terminated when the plume dissipation rate decreases to ambient levels.

9.15 TAPM is supplied with databases of terrain, vegetation, soil type, sea-surface temperature, and synoptic or large scale meteorological analyses for the period 1997-2001. After the model has run, the user can process the output data in various ways through the interface and analyse the results.

9.16 The model output files include, general meteorology (as hourly averages) and final plume rise centreline heights for the point source(s).

9.17 Output meteorological files can be created in formats suitable for use directly with simpler dispersion models such as, AUSPLUME or ISC3, if required.

9.18 TAPM, in its proprietary form, is only able to model plumes originating from a point source. The algorithms may need to be modified by the user, or an alternative software application utilised, to simulate the plume rise from an area, a line or a volume source.

9.19 TAPM contains a buoyancy enhancement factor to handle overlapping plumes from multiple stacks. Alternatively, overlapped plumes can be modelled using another software, or empirical application, to determine resultant characteristics at the location where the plumes become fully merged. These merged plume characteristics can then be adopted as the source in the TAPM plume rise module.

10. WHAT INFORMATION NEEDS TO BE PROVIDED TO CASA?

10.1 Applicants for a hazard assessment must provide CASA with an electronic data file of all model simulations undertaken for the plume assessment. This will be retained for future reference and/or used for the purpose of a random compliance audit.

10.2 Summary findings suitable for use in the aeronautical assessment should be presented in a written Impact Assessment Report.

10.3 The Impact Assessment Report shall provide a probability distribution for the height and lateral limit of the plume vertical velocity of 4.3 m/s and, where applicable, the probability of activation and duration for each plume event associated with the combustion source(s).

10.4 Detailed guidelines for the use of TAPM and the provision of the data required by CASA for a hazard assessment are included at Attachment A.

10.5 The form to be completed when requesting an Operational Assessment of a Proposed Plume Rise is included on the CASA Forms for Advisory Circulars web page http://casa.gov.au/manuals/htm/adv_circ/advfrm.htm.

11. WHO BEARS THE COST OF A HAZARD ASSESSMENT?

11.1 Proponents of a facility, which generates an exhaust plume with a vertical velocity greater than 4.3 m/s at the OLS for an aerodrome or greater than 110 metres above ground level, will be required to bear all costs associated with a hazard assessment.

11.2 In the case where the CASA determination requires amendment to Airservices Australia documentation, these costs will also be borne by the proponent.

12. FURTHER INFORMATION

12.1 Further information on plume rise assessments can be obtained from the aerodrome specialists in the Aerodrome Standards Section of CASA. You can contact them on 131 757.

12.2 A list of consultants who specialize in plume rise assessments can also be found on the CASA Web Site at www.casa.gov.au/avreg/aerodromes/consultrequest.htm.

Bill McIntyre
Executive Manager
Aviation Safety Standards

Attachment A

Using TAPM V2.0 for Plume Rise Assessments

Meteorological and Grid Related User Inputs

The meteorology and grid related model inputs should be the default TAPM inputs, except for the following:

- The modelling period should be a continuous period of at least 5 full years
- The entire horizontal grid domain should be a square region with 25 by 25 (or more) grid points, with a 30 km outer grid and two nested grids at 10 km and 3 km
- A further sub-3km nested grid may be added at the user's discretion provided it is not less than 800 m
- The horizontal domain should be less than 1000 km by 1000 km
- The number of vertical levels should be at least 25
- The grid centre coordinates should be as close to the plume source (or centroid of the sources) as allowed by the resolution of the user interface
- Terrain height database should be extracted from the AUSLIG 9 second DEM database for the region under consideration
- The user may input site-specific geographical data such as, monthly sea surface temperature, land use data and deep soil moisture content, provided it is objectively demonstrated that the data used is more appropriate than the default TAPM data for that region
- Monitored meteorological data may be assimilated into the model provided it is demonstrated to be of high quality and of the appropriate type (e.g. hourly averaged data)
- Users may select the "Rain Processes" option at their own discretion
- Users may select the "Prognostic Eddy Dissipation Rate" option at their own discretion

User Inputs for Single Point Source or Non-Merged Plumes

The guidelines for the point source specifications are as follows:

- The source position should be correctly located with respect to the grid centre
- Buoyancy enhancement should be set to 1

Merged Plumes or Non-Point Sources

TAPM v2.0 is not suitable for the determination of plume rise dynamics for plumes that merge significantly or for plumes that do not originate from point sources (such as a buoyant line source). For such sources, TAPM should be run in meteorology-only mode using appropriate input parameters as outlined in the "Meteorological and Grid Related User Inputs" section on the previous page. The resulting 5 full years of hourly averaged upper level meteorological data should be used in the solution of the TAPM plume rise equations that have been suitably modified by the user to account for the effect of height dependent plume merging or the non-point source nature of the emitted plume. Impact assessment reports must detail the equation modifications and provide appropriate justification for the methods used.

Data Analysis and Presentation

The analysis of plume rise dynamics, and upper level winds, should include data from every hour of the full 5 years of hours modelled. Analysis and presentation should comply with the following:

- Plume dynamics analysis should consider average plume velocities
- Horizontal displacement of the plume centreline, and plume spread about the centreline, should be evaluated as a function of height for each hour using the TAPM generated upper level meteorological wind speed and direction along with the calculated plume spread. Combining this with corresponding average vertical plume velocity (as a function of height for that hour) the regions of space for which all or part of the plume exceeds the critical velocity at any time within the modelled period should be determined. These horizontal regions should be plotted for at least 8 well-spaced heights above the ground ranging from the height of the point source to the maximum height at which the average vertical velocity reduces to the critical vertical plume velocity.
- Horizontal displacement of the plume centreline should be evaluated as a function of height for each hour using the TAPM generated upper level meteorological wind speed and direction. Combining this with corresponding peak vertical plume velocity as a function of height for that hour, the regions of space for which the centreline of the plume exceeds the critical velocity at any time within the modelled period may be determined. These horizontal regions should be plotted for at least 8 well-spaced heights above the ground ranging from the height of the point source, to the maximum height at which the peak vertical velocity falls to the critical vertical plume velocity.
- Wind speed cumulative frequency plots for at least 8 well-spaced heights ranging from the height of the point source to the maximum height at which the peak vertical velocity reduces to the critical vertical plume velocity should be generated and presented in graphical form in the impact assessment report.
- The percentage of the time that wind speeds are less than 0.1, 0.2, 0.3, 0.4 and 0.5 m/s, for at least 8 well-spaced separate heights ranging from the height of the point source to the maximum height at which the peak vertical velocity falls to the critical vertical plume velocity should be generated from TAPM's upper air meteorological data and presented in tabular form in the impact assessment report.

- The heights above the ground at which the average vertical velocity of the plume exceeds the critical vertical velocity for the following percentages of the time should be presented in tabular form in the impact assessment report: 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.3%, 0.2%, 0.1%, 0.05%.
- The maximum, minimum and average heights above the ground at which the average vertical plume velocities exceed the critical vertical velocity should be presented in tabular form in the impact assessment report.

Clean Air Conference, Newcastle, New South Wales, Australia, 2003

AVIATION SAFETY AND BUOYANT PLUMES

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Summary

Very buoyant plumes generally experience good dispersion but can, in some circumstances, affect aviation safety. Large in-plume vertical velocities can occur in calm conditions with minimal wind shear. Recent civil aviation guidelines seek to restrict the horizontal or vertical extent where average in-plume vertical velocities exceed a thréshold that can threaten aircraft performance or structural stability. Key plume calculation procedures require adequate predictions or measurements of vertical profiles of wind and turbulence parameters. The TAPM scheme proves useful but requires additional features for complex source geometry. A hybrid approach overcomes most of these limitations, whilst treating the initial plume development in more detail. Design issues for typical stack configurations are discussed.

Keywords: Plume velocities, stacks, cooling towers, flares, safety

1. Introduction

Over the past 25 years, considerable laboratory, field and theoretical work has been undertaken on the dispersion of very buoyant plumes from industrial sources. Such sources have traditionally included single or multi-flue stacks for major power stations, cooling towers and gas turbine generating plants where large volume flows, together with high exit temperatures, produce some of the highest buoyancy fluxes for normal power station configurations. With the increasing emphasis on gas and similar alternatives for power generation and the recent consideration of stack-in-tower configurations for locations where dry cooling is preferred, highly buoyant plumes are becoming the rule. In addition, industrial flares or unintended releases from pressurised pipelines can yield plumes with large momentum and/or buoyancy fluxes and may have structures approximating line or area sources. Recent dispersion analyses (Weil et al 2001) have shown that very buoyant plumes can readily interact with the overlying inversion and have plume spread dominated by buoyancy for most of the near-field. Plume rise and spread descriptions may need to be revisited.

High buoyancy plumes can, however, give rise to other problems that may require addressing in environmental impact assessments. High buoyancy plumes rise quickly and have significant in-plume vertical velocities. Should the facility be close to local airfields or aviation transport routes, any aircraft encountering the buoyant plumes may experience sufficient vertical uplift and turbulence to cause some temporary disruption to the manoeuvrability of aircraft, especially light commercial (rather than jet) aircraft.

There are no publicly-available field studies that document the decline of in-plume velocities with plume travel time for a variety of conditions necessary to produce validated modelling schemes. Various experimental and theoretical work was conducted around open-cycle and combined-cycle gas turbines at Kuala Lumpur, with field measurements taken for stack-top windspeeds in the range 2-8 m/s (but not for calm conditions). The Cessna aircraft used (Flinders Institute for Atmospheric and Marine Sciences) was fitted out to measure turbulence and air quality parameters as well as aircraft variables. The unpublished results showed a strong decrease of in-plume vertical velocities with windspeed and height, core vertical velocities a factor of approximately 2 greater than plume-averaged values and significant influences on aircraft handling for near-instantaneous (~ 1 sec) exposures to strong plume velocities, especially if encountered by surprise.

The importance of vertical motion in causing aviation problems is better documented by the number of light aircraft incidents reported during strong convection in Australia (Spillane and Hess 1988). During extreme events, naturally-occurring vertical velocities can reach 8 m/s.

The current studies were conducted for an environmental impact assessment of a 700 MW open cycle gas-fired turbine near an army aviation centre at Oakey in southern Queensland. Previous studies by Spillane (1980) on moist plumes were adapted to treat buoyant plumes from closely located sources in calm and low windspeed neutral conditions (Katestone

Scientific 1997). At the time, there was no model recommended by the Civil Aviation Safety Authority of Australia (CASA) and, indeed, very little guidance internationally as to the manner in which available velocity thresholds should be interpreted. Representations were made and generally accepted that the threshold vertical velocity of 4.3 m/s recommended by Australia and New Zealand authorities should be viewed as a plume-average rather than plume centreline criterion.

Critical (but extreme) aviation conditions are expected to be very light winds and neutral stability to heights of 500 m or more. For most assessment sites, there is unlikely to be a substantial database of near-surface and upper-level wind and temperature information to estimate the frequency of occurrence of such rare cases. Recognising this, CASA recently recommended the use of the CSIRO TAPM model for producing long-term databases of such profiles at any location within Australia and for providing a publicly-available method of calculating plume vertical velocities in the near-field of a single plume source (CASA 2003). The TAPM treatment of plume rise (Hurley and Manins 1995) uses coupled non-linear first-order differential equations for the plume volume G, buoyancy F and momentum M fluxes that are generalisations of the original Briggs (1975) plume rise formulation, based on the work of Glendening et al (1984) for stable atmospheres with complex structures. The TAPM scheme does not include any influence of source-altered flow fields or moisture content. It is also strictly valid only for single sources, with multiple sources being treated only via use of a plume enhancement factor, a relatively coarse device for describing near-field plume dynamics. For cooling tower sources, moisture emissions, the confluence of adjacent plumes and the influence of suction occurring due to tower bypass flow can be important (Rezacova and Sokol, 2000). This paper restricts attention to essentially dry plumes with no interactions with distorted flow fields.

Aviation safety risk assessments require the evaluation of concurrence of adverse vertical velocities with the presence of aircraft in the vicinity of the plume and a spectrum of aircraft types and pilot skill. Ideally, a generalised scheme should facilitate the prediction of likely pilot response to such events but publicly-available schemes are not yet available. As for many air quality problems, the main difficulties are assessing the relevance of traditional techniques to the forecasting of extreme conditions and determining the reliability of such assessments based on existing knowledge.

The present paper outlines the available plume calculation methodologies for the Spillane and TAPM approaches, addresses the modifications necessary for multiple sources and assesses the utility of the various schemes for dispersion and meteorological modelling in providing initial and detailed assessments. The high buoyancy of the plumes diminishes the utility of various design alternatives such as increasing stack separation, reducing exit velocity and changing the orientation of discharge. Practical measures are discussed.

2. General considerations

For the generic stack problem, we choose the case of multiple but identical sources of high initial exit velocity and temperature but low enough water vapour content to neglect latent heat considerations. In light winds, influences of the aerodynamic wakes or other effects of stack or cooling tower structures can be neglected. The initial stage (exit conditions) is assumed to be a plume emanating from a stack of height h_s and diameter D, with plume exit velocity either uniform over the cross-section (with a value V_{exit}) or, more likely, a non-uniform velocity profile with plume average velocity V_{exit}. The exit virtual potential temperature θ_s, volume flow $\pi D^2 V_{exit}/4$ and initial buoyancy flux $F_o = gV_{exit} D^2 (1 - \theta_a/\theta_s) / 4$ are readily calculated, with θ_a denoting ambient conditions. The ambient airspeed at stack top is denoted u_e with $K_o = V_{exit}/u_e$ being the initial plume to ambient velocity ratio.

An outline is given in the following sections of the Spillane and TAPM plume dynamics modules for single plumes (retaining their respective notations). The physical interpretation of the processes is outlined in Section 3 with the additional considerations needed for multiple plumes.

2.1 Spillane methodology

The plume radius a, orientation ϕ and velocity V are followed along the plume trajectory. Five equations are solved numerically for the normalised vertical velocity $K = V/u_e$:

Radial growth of a forced-plume bending in a wind:

$$\frac{da}{ds} = \beta_n \cos\phi / K + \beta_e \left| 1 - \frac{\sin\phi}{K} \right| \qquad (1)$$

Rate of entrainment, E, into the plume:

$$2E/V = \left(\frac{da}{ds} + (\lambda^2 \cos\phi)/2F_r^2\right)/(1 - \sin\phi / 2K) \qquad (2)$$

Momentum flux, Va, (longitudinal)

$$\frac{d(Va)}{ds} = 2E - V\frac{da}{ds} \qquad (3)$$

Trajectory curvature; transverse momentum flux

$$\frac{d\phi}{ds} = \left(2\,Ea\,u_e \cos\phi - (F \sin\phi)/2.25V\right)/(Va)^2 \qquad (4)$$

Flux of heat:

$$\frac{d\left(Va^2 \Delta\theta / \theta\right)}{ds} = 0, \text{ in a neutral environment} \qquad (5)$$

where the notation is as follows:

a = plume top-hat radius;
s = distance along plume trajectory;
ϕ = angle of plume centre line to vertical ;
K = V/u_e;
V = plume-averaged speed.
β_n = 0.40; β_e = 0.16; λ = 1.11;
F_r^2 = Froude No = $V^2/(ag\Delta\theta/\theta)$
F = flux of buoyancy = $\lambda^2 a^2 V g\ \Delta\theta/\theta$; $\Delta\theta = \theta_p - \theta_e$ and suffices p and e for plume and environment.
θ = virtual potential temperature.

Initial conditions for ϕ, V, a and z are set for the end of the momentum rise stage (for a single plume) or at the end of the merged plume stage (for multiple plumes). An along-plume distance step of Δs = 20 m is used, and the appropriate value of $u_e(z)$ adopted for non-uniform profiles.

For the case of calm conditions, analytic solutions are possible, one for the product Va at any height, the other a linear increase of a = 0.16 (z - z_v) where the virtual source height (above stacktop) z_v = 6.25 D [1 - $(\theta_e / \theta_s)^{1/2}$]. For z > 6.25 D > z_v we have:

$$(Va)^3 = (Va)_o^3 + 0.12 F_o \left[(z - z_v)^2 - (6.25D - z_v)^2 \right]$$
$$\text{where } (Va)_o = V_{exit} D / 2 (\theta_e / \theta_s)^{1/2} \qquad (6)$$

2.2 CSIRO TAPM methodology

The TAPM mean plume rise estimation takes the Glendening et al (1984) approach but assumes that the horizontal plume velocity instantaneously takes up the ambient horizontal velocity at stack height. Cartesian co-ordinates are adopted. The differential equation for plume volume flux G:

$$\frac{dG}{dt} = 2R\ w_p \left(\alpha\ w_p + \beta\ u_e \right) \qquad (7)$$

neglects a third term due to ambient turbulence entrainment. $w_p = \frac{dz_p}{dt}$ is the plume vertical velocity, α = 0.1 and β = 0.6 are vertical and bent-over entrainment coefficients and R is the plume radius. For the buoyancy flux F, it assumes:

$$\frac{dF}{dt} = -\frac{sM}{u_p} \left(A u_a + w_p \right) \qquad (8)$$

where $s^2 = \frac{g}{\theta_a} \frac{\partial \theta_a}{\partial z}$ gives the ambient buoyancy frequency (s = 0 in neutral conditions), $u_p^2 = u_e^2 + w_p^2$, A = 1/2.25 and M is determined by $\frac{dM}{dt}$ = F (= F_o in neutral conditions). By definition,

$$G = \frac{\theta_e}{\theta_p} u_p R^2,\ F = g u_p R^2 \frac{\Delta\theta}{\theta_p},\ u_p R^2 = G + F / g,$$
$$w_p = M/G \qquad (9)$$

Initial conditions are set with G, F and M evaluated with $w_p = V_{exit}$, R = R_s = D/2 but with the initial integration having

$$R = R_o = R_s \left(V_{exit} / \left(u_a^2 + V_{exit}^2 \right)^{1/2} \right)^{1/2} \qquad (10)$$

The plume rise height is terminated when F = 0 and plume and ambient dissipation rates are equal. The plume dimensions are based on R = 0.4 (z - h_s) or equivalent prescriptions.

3. Treatment of multiple plumes

For N multiple, identical sources with stack separation d, Table 1 summarises the expected multi-stage plume development as well as Figure 1. The first stage is the rapid (almost vertical) rise of the individual plumes due to their momentum. The external surface of the plume entrains air as it rises (and the vertical velocities are reduced). The end of the momentum-dominated phase occurs when this entrainment reaches the plume core, the plume centreline has a vertical velocity equal to V_{exit} and the velocity profile will be essentially Gaussian. The peak (core) vertical velocity is therefore V_{exit} but the plume average value is 0.5 V_{exit}. Conservation of momentum therefore requires the plume width to have effectively doubled from its initial value a_o.

In this first phase, the plume travels a height of 6.25 D in calm conditions and 0.4 $K_o a_o$ for K_o reasonably large (based on laboratory experiments). Davidson (1994) has also shown that an analytic form for plume rise in a uniform wind has an initial component of 6.2 D exp (-3.3/K_o).

In the second stage, the plume dynamics and trajectories respond to ambient conditions, with much cooler air being entrained into the stack plume. The buoyancy of the plumes has significant influences on the rise as this air mixes into the plume and provides dilution of the exhaust. This dilution is very sensitive to ambient wind speed. For multiple plumes from closely-spaced stacks, this leads almost immediately to a height at which two plumes first touch each other (and plume merging commences) when the effective plume radius is equal to half the stack separation (this is exact in calm winds and approximately correct for light winds). Total merging is assumed to occur when the single plume radius equals stack separation. Conservation of buoyancy flux and Froude number (a reasonable assumption for coherent plumes) leads to a conclusion that the plume radius and vertical velocity will be increased overall by a factor of $2^{0.25}$ = 1.189 by the merging of 2 adjacent plumes.

For more than two stacks, the situation is more complex. In calm conditions, the combined plumes from pairs of stacks will coalesce shortly after to form a coherent plume, assumed to be complete before the single plume radius, a^{sp}, is ½ d (N-1) At this height, the combined plume velocity V_m and radius a_m are $N^{0.25}$

greater than for a single plume. For non-calm conditions, a simplified treatment shows that total merging is likely to occur soon after the merging of two adjacent plumes, for winds at right angles to the line of separation of the stack. For winds at smaller angles ω to the line of stacks, the process is more sequential and the effective stack separation can be reduced by a factor proportional to $\cos \omega$.

In the third stage of plume development, plume rise is due entirely to the buoyancy of the (merged) plume and continues until there is an equalisation of turbulent conditions within and outside the plume. The effective average vertical velocity is then close to zero. The third stage of plume development can then be treated as that of a single merged plume (with different initial conditions for a, V and ϕ) passing through different atmospheric layers with varying horizontal velocity u_e. The Katestone software uses a simple successive substitution method to determine a, E (the entrainment), V and ϕ in that order. These equations are valid up to a critical value of ϕ_c ($\phi_c < \pi/2$) at which either the assumptions become invalid or plume rise should be effectively terminated.

These equations can be used in the second stage prior to plume touching and in the third stage once merging has been completed. Plume height is calculated by aggregating $\Delta s \cos \phi$, centreline displacement by aggregating $\Delta s \sin \phi$. For each Δs, the appropriate ambient windspeed is determined by linear interpolation (or power law curve fitting of available meteorological profile measurements or predictions).

A fourth stage can occur if the coherent plume reaches the base of the overlying inversion (height Z_i). Some of the plume will punch through the inversion base, albeit with reduced vertical velocity. The remainder will be effectively trapped within the inversion layer with essentially zero vertical velocity. Weil et al (2001) show that the penetration in convective conditions depends on $F_*^{2/3}$ where $F_*=F/(u_e w_*^2 Z_i)$ and w_* is the convective velocity scale. There is as yet little guidance on plume dimensions and vertical velocity for the penetrative component.

Table 1: Key parameters for the various stages of development for merging plumes.

Stage	Average plume velocity		Plume width	Plume height	Plume angle	Comments
	Vertical	Horizontal				
Stack exit	V_{exit}	0	a_o	h_s	0°	
End of jet phase	$0.5\ V_{exit}$	$u_e(z) + V \sin \phi_o$	$2a_o$	$h_s + z_o$	ϕ_o	$z_o = K_o a_o < 6.25D$
Plumes first touch	$V_t \cos \phi_t$	$u_e(z) + V_t \sin \phi_t$	a_t	z_t	ϕ_t	$V_t < 0.5\ V_{exit}$
End of plume merging	$V_m \cos \phi_m$	$u_e(z) + V_m \sin \phi_m$	a_m	z_m	ϕ_m	$a_m \approx N^{1/4}\ a^{sp}$ $V_m \approx N^{1/4}\ V^{sp}$
Coherent merged plume	$V \cos \phi$	$u_e(z) + V \sin \phi$	a	z	ϕ	$V < V_m\ a > a_m$
Maximum plume rise	0	$u_e(z) + V \sin \phi$	a_c	z_c	ϕ_c	$\phi_c < 90^o$
Inversion interaction	Low	Shear-affected	Enhanced	$> Z_i$	Variable	(Weil et al 2001)

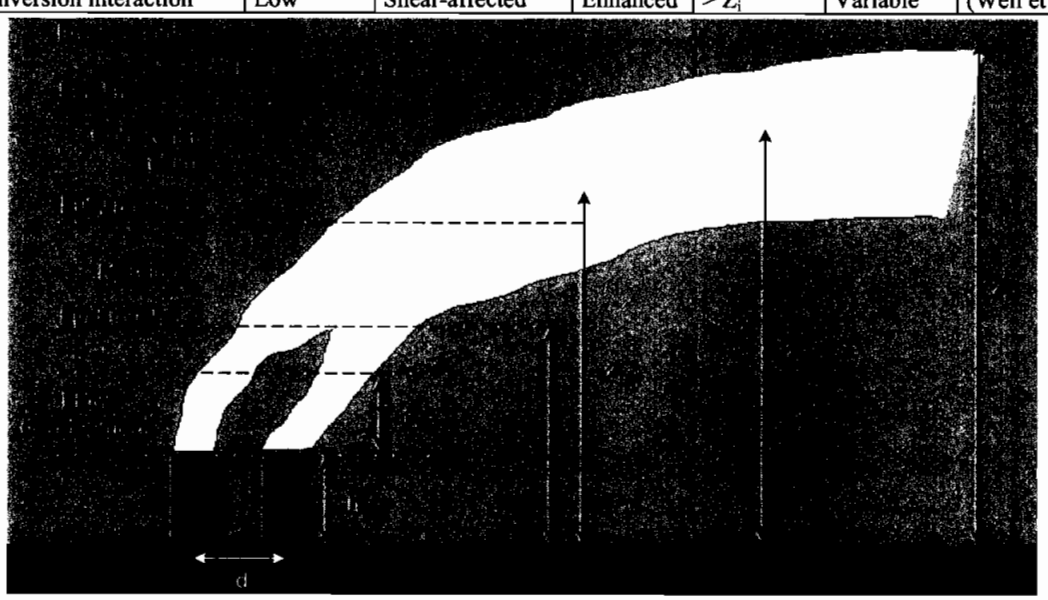

Figure 1: Schematic of plumes merging.

4. Illustrative examples

The simplest cases assume identical sources with stack separation d operating in a neutral and unbounded atmosphere with uniform conditions. For the Spillane approach, Table 2 gives the resulting plume-average vertical velocities for the cases with V_{exit} = 38.9 m/s, h_s = 35 m, F = 2300 m^4/s^3 and N = 1 and separately N = 2 with d = 25 m.

The heights experiencing threshold exceedances are dramatically reduced going from calm to light winds. The TAPM approach for single plumes gives similar results if some allowance is made for an initial displacement offset z_0 (Figure 2).

Table 2: Plume average vertical velocities (m/s) for uniform calm and light wind conditions in a neutral atmosphere

Height	Calm		u_e = 1.5 m/s		u_e = 3 m/s	
	Single	Double	Single	Double	Single	Double
100	12.2	12.2	9.0	9.3	6.9	8.3
200	7.8	9.2	5.5	7.0	3.6	5.1
300	6.5	8.0	4.4	5.8	2.6	3.9
500	5.3	6.6	3.2	4.5		2.8
700	4.8	6.0	2.6	3.7		2.2
1000	4.1	5.2				

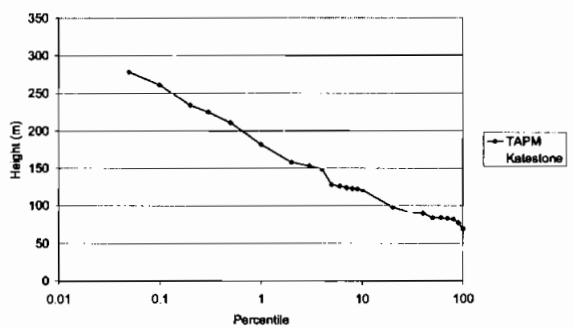

Figure 2: Comparison of methodologies for plume height calculations for a 5 year period.

5. Meteorological modelling

Meteorological inputs are critical for a reasonable treatment of risk, especially for near-calm conditions at stack-top and above. Unfortunately, it is these very conditions under which near-surface measurements (together with stability-dependent profile laws) or TAPM-like prediction methodologies are likely to be poor indicators of actual conditions, at least for inland sites (Jackson et al 2003). Presumably this quandary lead CASA to recommend the TAPM approach. If measurements are available from a nearby 30-100 m tower, we would recommend their use unless TAPM results are carefully tuned to the appropriate surface conditions.

Recent project work near Williamtown Airport gave a comparison of five years of hourly TAPM results with available balloon and 30 m tower measurements. The main conclusions were:

- Moderate interannual variability in the actual and predicted occurrence of light winds at 30 m and above.
- TAPM tends to underpredict the frequency of occurrence of very light winds (< 1 m/s) compared to tower observations (typically 1.2 - 3.5% compared to 5.7 - 14.9%).
- For available balloon profiles, TAPM overpredicted the frequency of very light winds at 600 m and 900 m agl.
- Very few measurements are available in the crucial 100-500 m height range.

6. Synthetic approaches

The Spillane approach has been adapted to take in the TAPM wind profile conditions. Figure 3 compares the cumulative probability distributions for critical heights (where the in-plume average velocity drops below 4.3 m/s) obtained by using either the TAPM wind predictions or the interpolated measured winds, for the case of two 35 m high, 54 m separated combined-cycle units of total capacity over 800 MW. Close agreement is obtained.

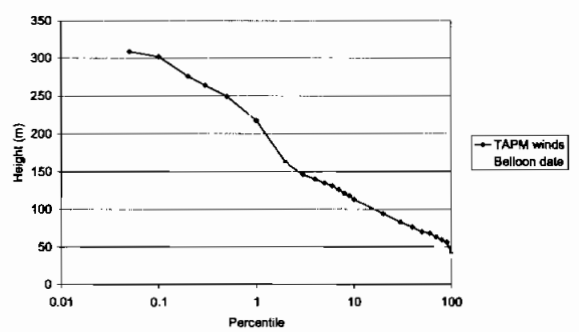

Figure 3: Comparison of Spillane plume height calculations for TAPM - generated and measured winds.

7. Design options

Decreasing the exit velocity will reduce the initial flow development length but plume buoyancy is the key factor in the magnitude of the vertical velocity. Similarly any reduction in stack height gives little benefit to aviation safety concerns and may risk poor plume dispersion in high-wind conditions (due to building wake influences). Increasing the stack separation does delay the time when plumes merge but with little overall practical benefit (Figure 4). Horizontally-pointing stack exits will reduce initial momentum but again buoyancy is dominant.

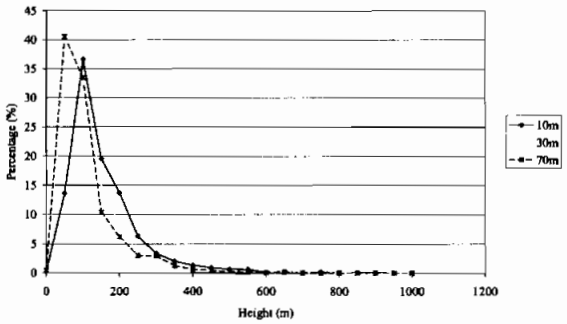

Figure 4: Frequency of critical height for varying stack configurations.

The reduction of plume buoyaney by using heat recovery results in a very significant reduction of critical heights but open-cycle operation usually has to be considered in any risk assessment. For eritical eases, it appears better to take advantage of the relatively small zone of influence on vertical velocities and the usual requirement of CASA to identify stack locations for low-flying aircraft. A notice to aircrew together with real-time indication of site operations may be effective in most situations.

8. Conclusions

Methodologies now exist for major point sources and point to the dominating role of initial plume buoyancy. Detailed measurements are required for light-wind conditions and are readily taken by experienced research aircrews. TAPM methodologies are reasonable for single plumes but inappropriate for multiple plumes. For key sites, remote sensing equipment is required to gather reliable wind statistics in the critical 100-500 m range. Theoretical advances are needed to treat inversion penetration in very light-wind conditions and to extend the methods to moist plumes and different source geometries.

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AVIATION WEATHER

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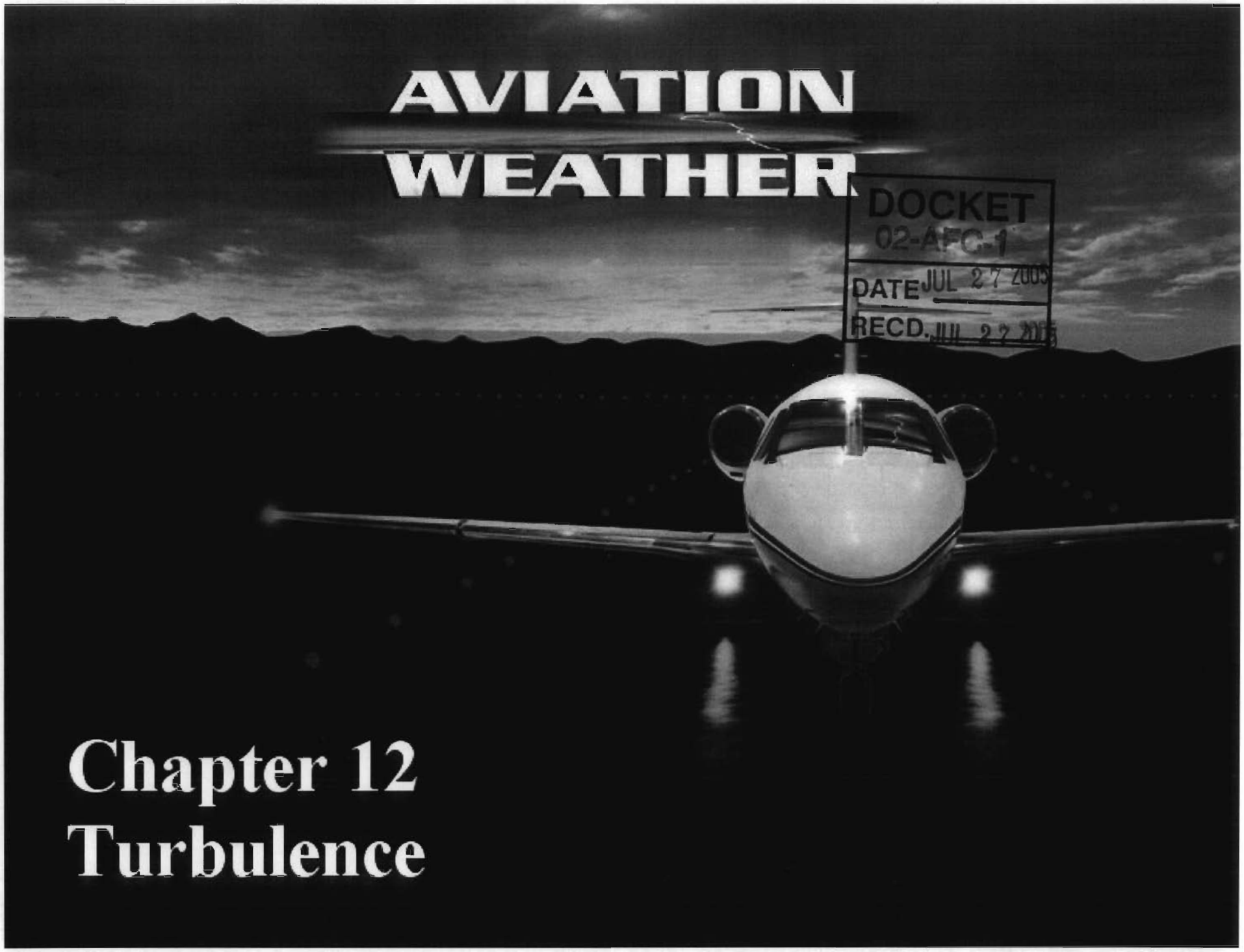


Chapter 12
Turbulence

Definitions

- Aviation turbulence
  - Bumpiness in flight
  - Based on response of the aircraft rather than the state of the atmosphere
- Turbulent gusts
  - Vertical gusts have more of an effect than horizontal gust
  - Horizontal gusts are hazardous in microbursts, mountain waves, and rotors

TURBULENCE REPORTING CRITERIA TABLE

Intensity	Aircraft Reaction	Reaction Inside Aircraft
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as light turbulence or light CAT. or Turbulence that causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as light CHOP.	Occupants may feel a slight strain against belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate	Turbulence that causes changes in altitude and/or attitude occurs but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as moderate turbulence or moderate CAT. or Turbulence that is similar to light CHOP but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Report as moderate CHOP.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as severe turbulence or severe CAT.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.
Extreme	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as extreme turbulence or extreme CAT.	

Pilots should report locations(s), time (UTC), altitude, aircraft type, whether in or near clouds, intensity, and when applicable, type (CHOP/clear air turbulence [CAT]), and duration of turbulence. Duration may be based on the time the pilot is flying between two locations or over a single location.

High-level turbulence (normally above 15,000 feet AGL) that is not associated with cumuliform clouds (including thunderstorms) shall be reported as CAT.

Quantitative Indications

- G-load
  - Caused by the influence of gravity
- Airspeed fluctuations
  - Average between the highest and lowest fluctuation
- Rate of Climb
  - Largest positive or negative values during horizontal flight

	Airspeed Fluctuation (kts)	G-load (g)	Derived Gust (f.p.m.)
Light	5 – 14.9	0.20 – 0.49	300 – 1199
Moderate	15 – 24.9	0.50 – 0.99	1200 – 2099
Severe	≥25	1.0 – 1.99	2100 – 2999
Extreme	—	≥2.00	≥3000

Causes and Types

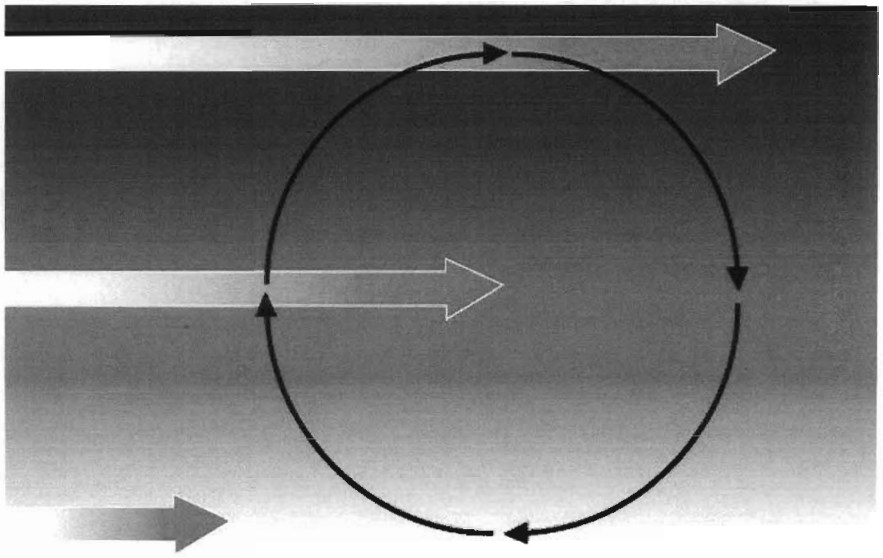
- Low-level turbulence (LLT)
- Turbulence in and near thunderstorms (TNT)
- Clear-air turbulence (CAT)
- Mountain wave turbulence (MWT)

Low-Level Turbulence (LLT)

- Defined as turbulence below 15,000 MSL
- We are looking at it as that contained in the boundary layer.
- Types of LLT
  - Mechanical
  - Thermal
  - Frontal

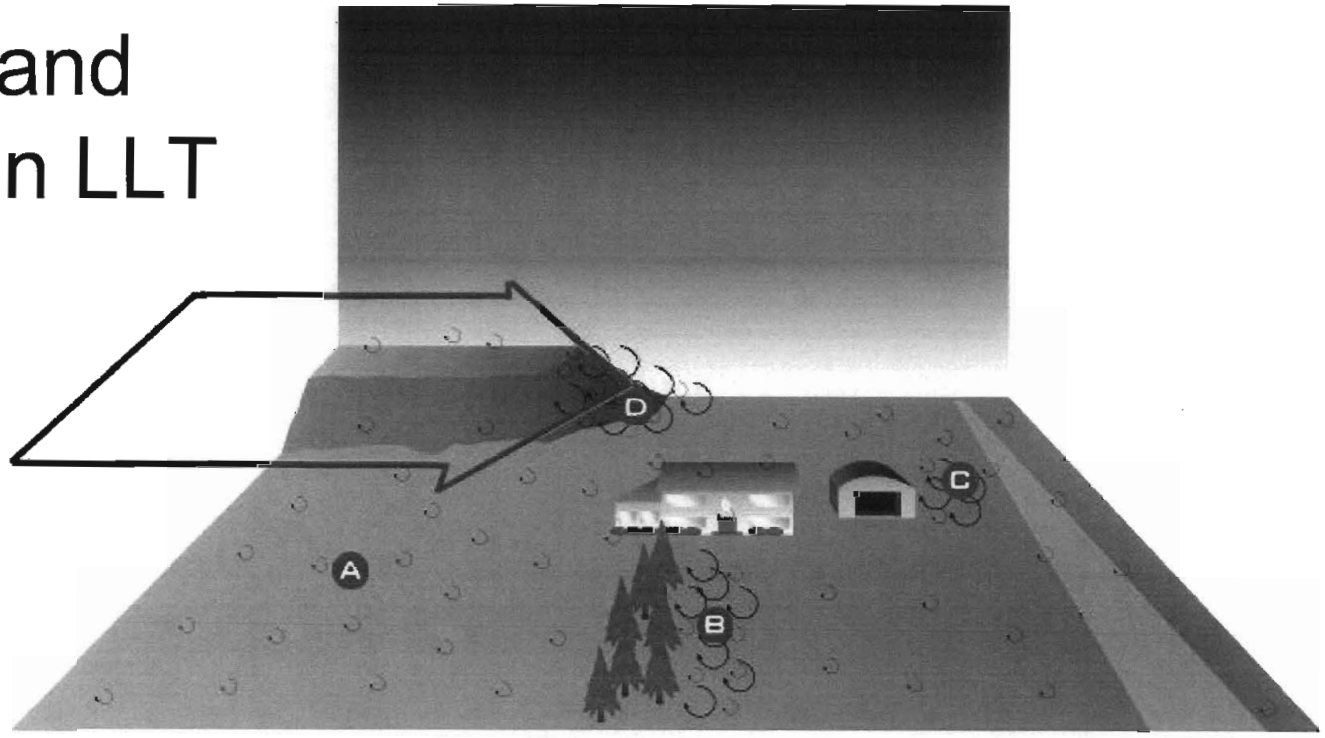
Mechanical Turbulence

- Strong surface winds
- Caused by friction
- Winds > 50kts turbulence can reach 3,000 AGL

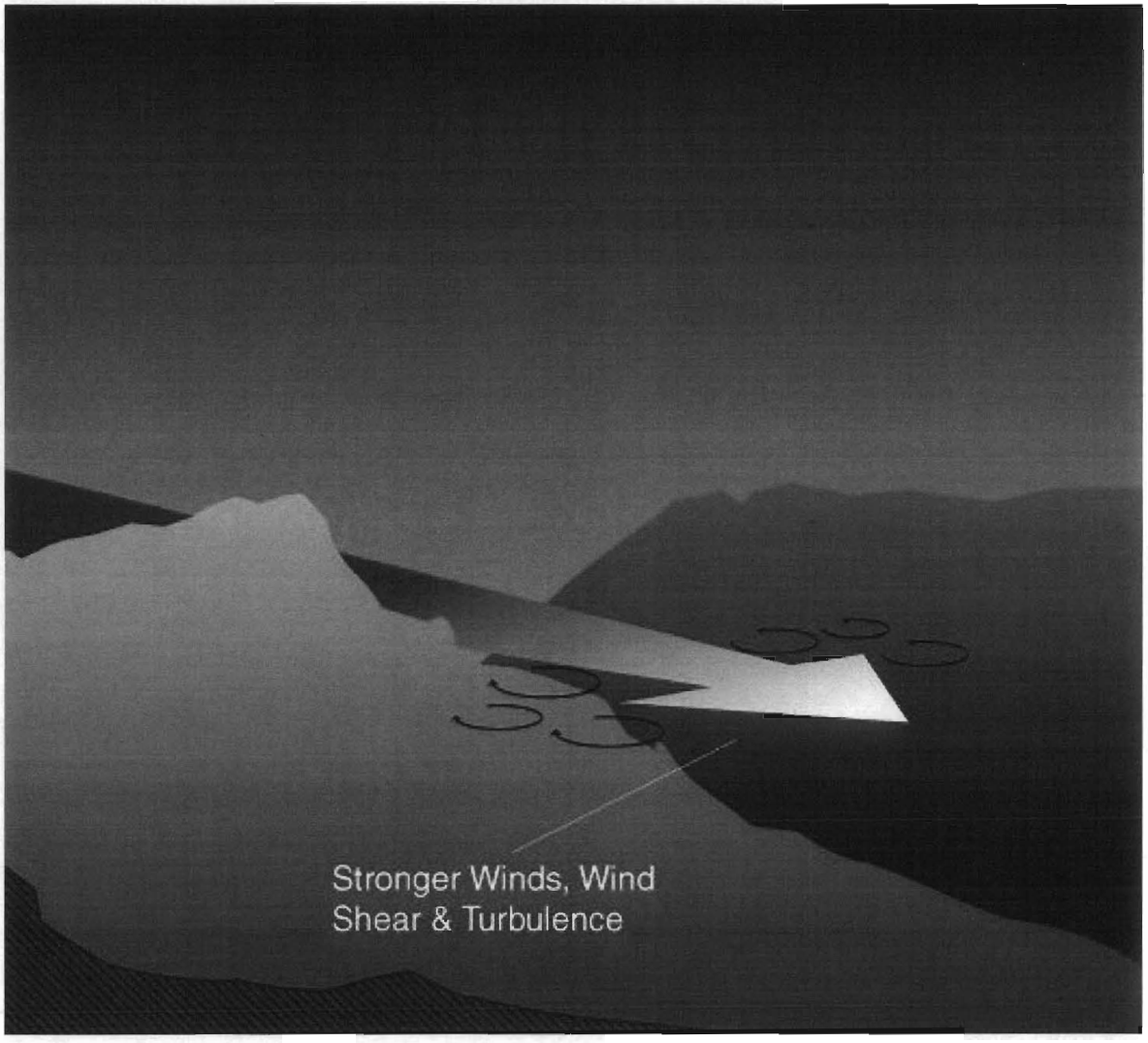


Mechanical Turbulence

- Obstructions increase and strengthen LLT

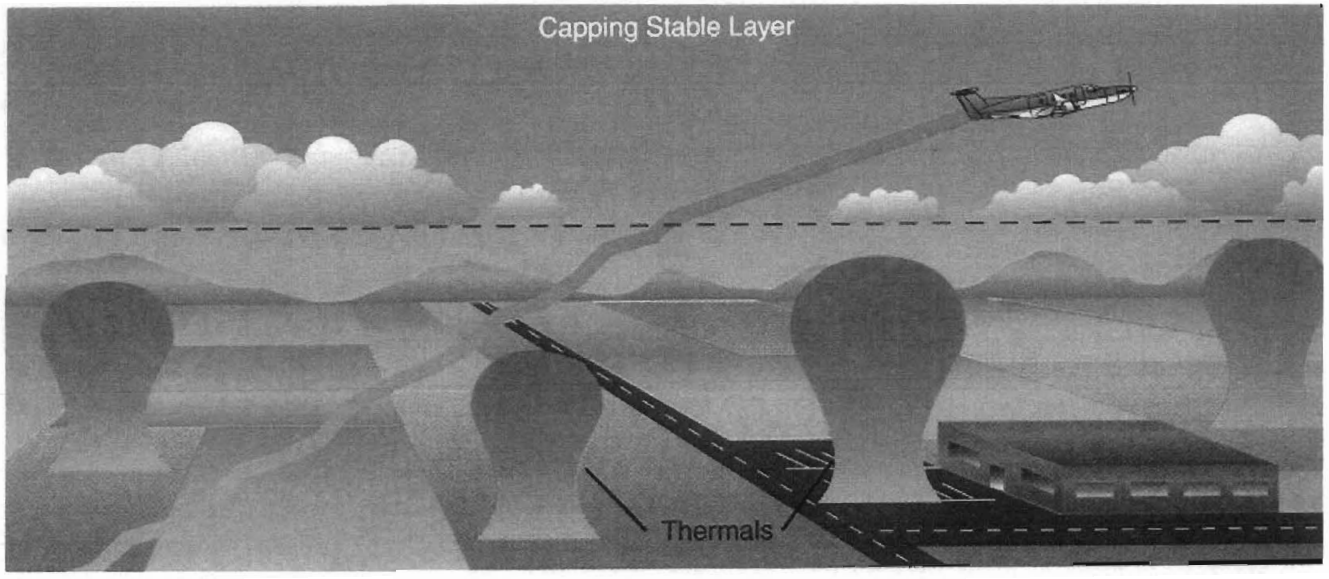


Valley Turbulence



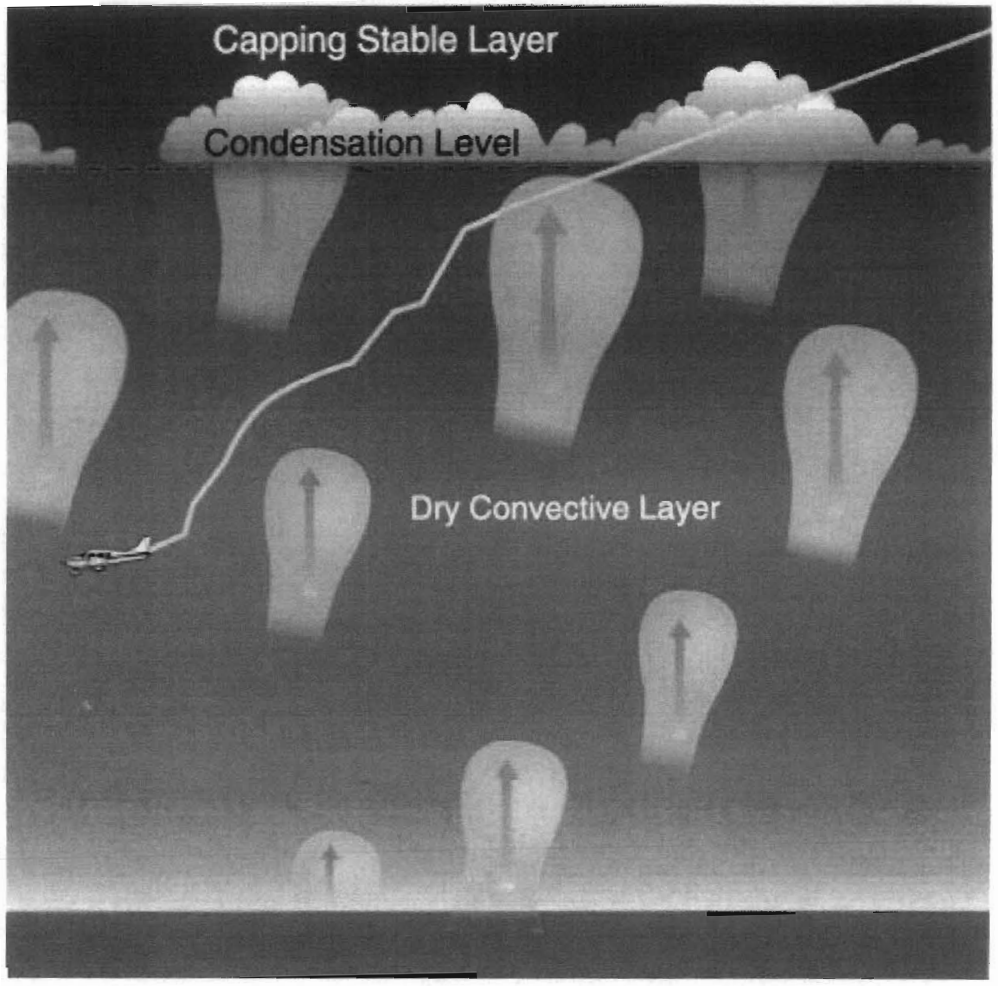
Thermal Turbulence

- Produced by dry convection in the boundary layer
- Reaches a maximum in the afternoon
- Thermal plumes and dust devils are common when the ground is very hot



Thermal Turbulence

- As thermals move away from the ground they grow in size
- Horizontal dimension is proportional to its height above the ground
- Range fro 200 – 400 fpm to extremes of 1,000 – 2,000 fpm
- Capping Stable Layer

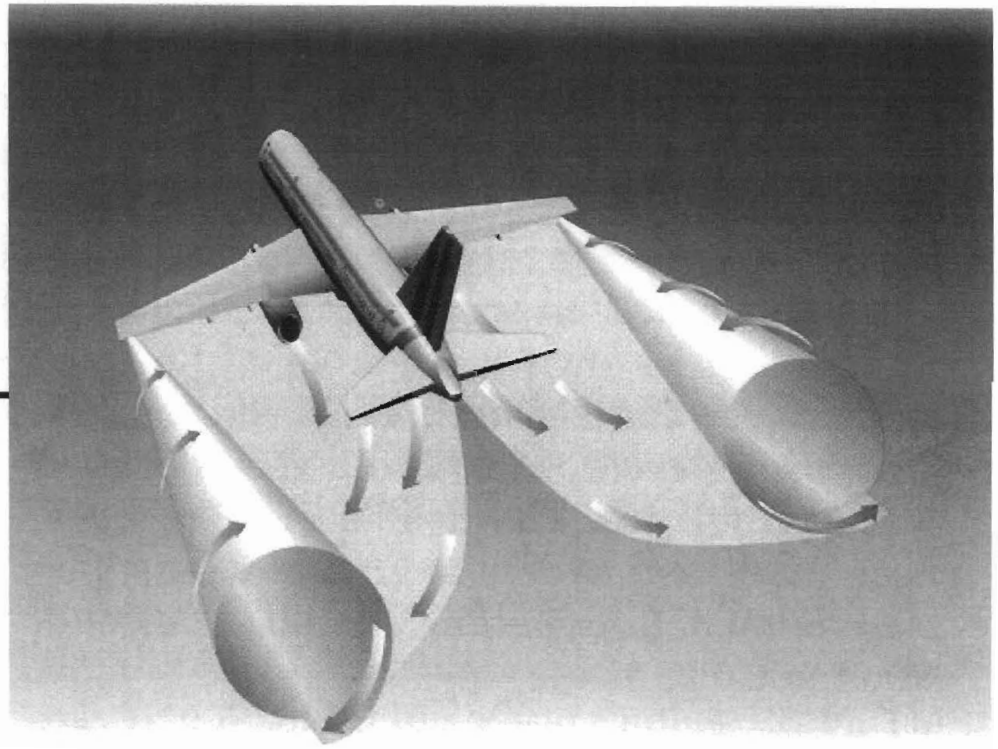


Frontal Turbulence

- Associated with fast moving cold fronts
  - 30 kts or more will generate moderate or greater LLT
- Over rough terrain all fronts are capable of producing moderate or greater LLT regardless of their speed

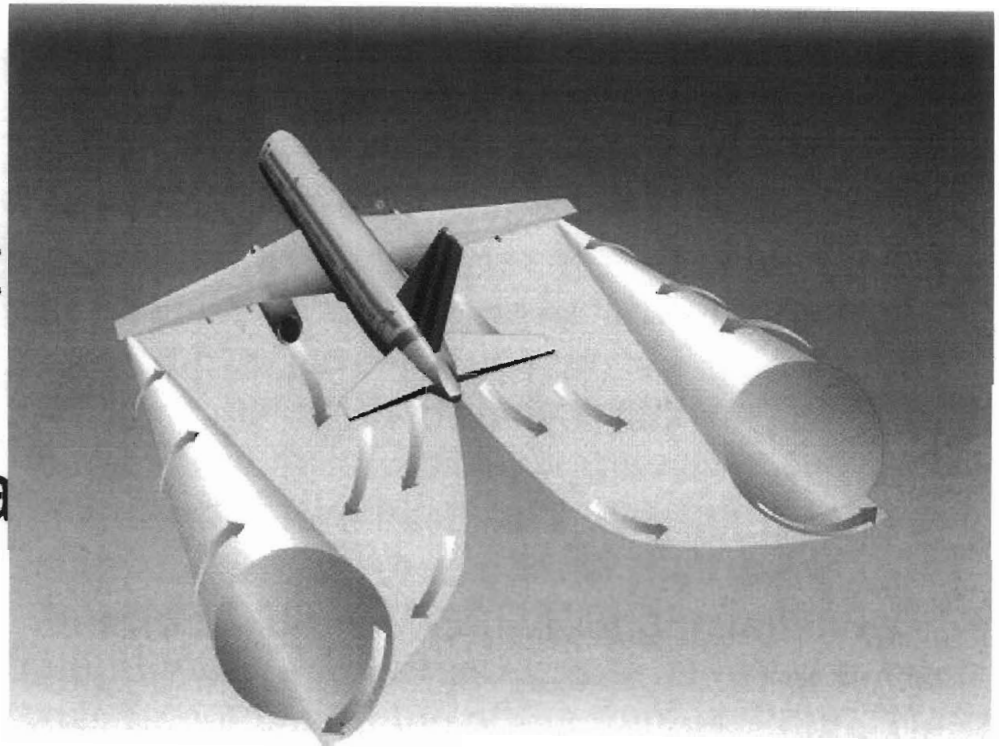
Wake Turbulence

- 2 counter-rotating vortices
- Begin at liftoff and end at touchdown
- Fully formed at 2 – 4 wingspans
- Typically 25 – 50 feet in diameter

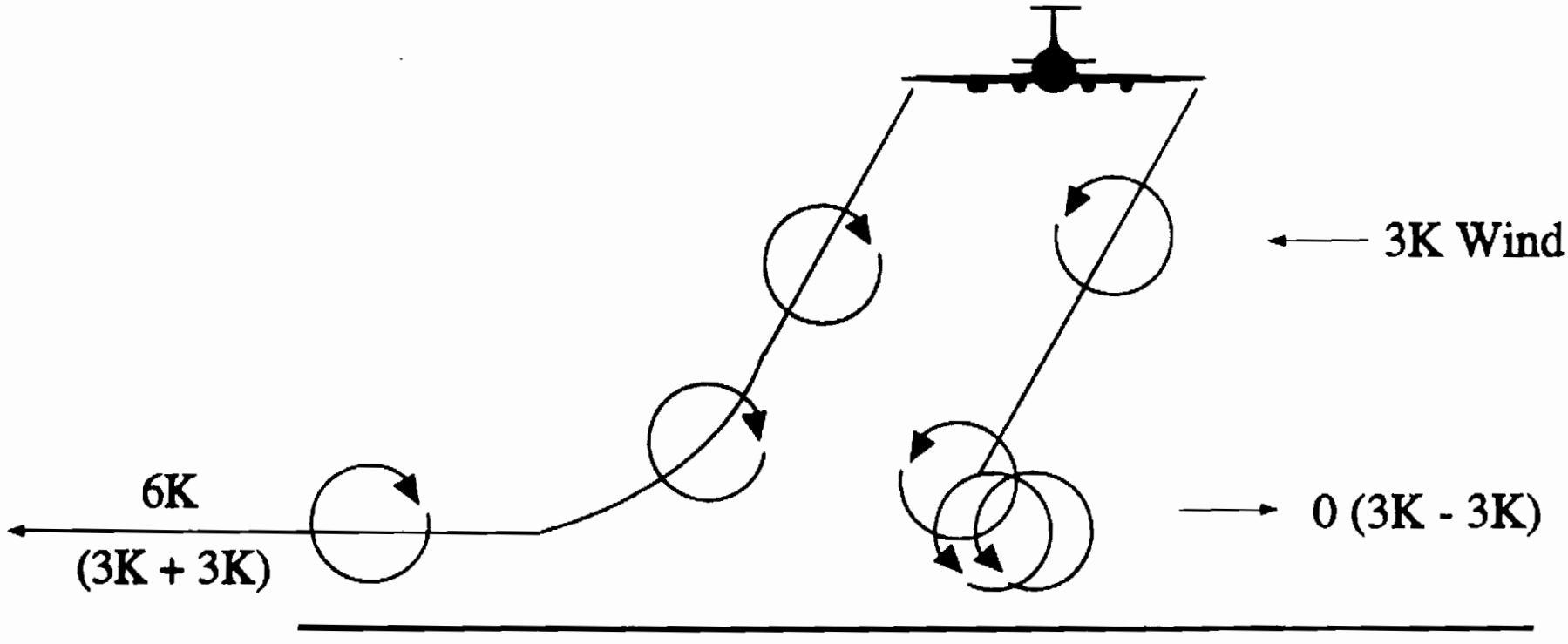


Wake Turbulence

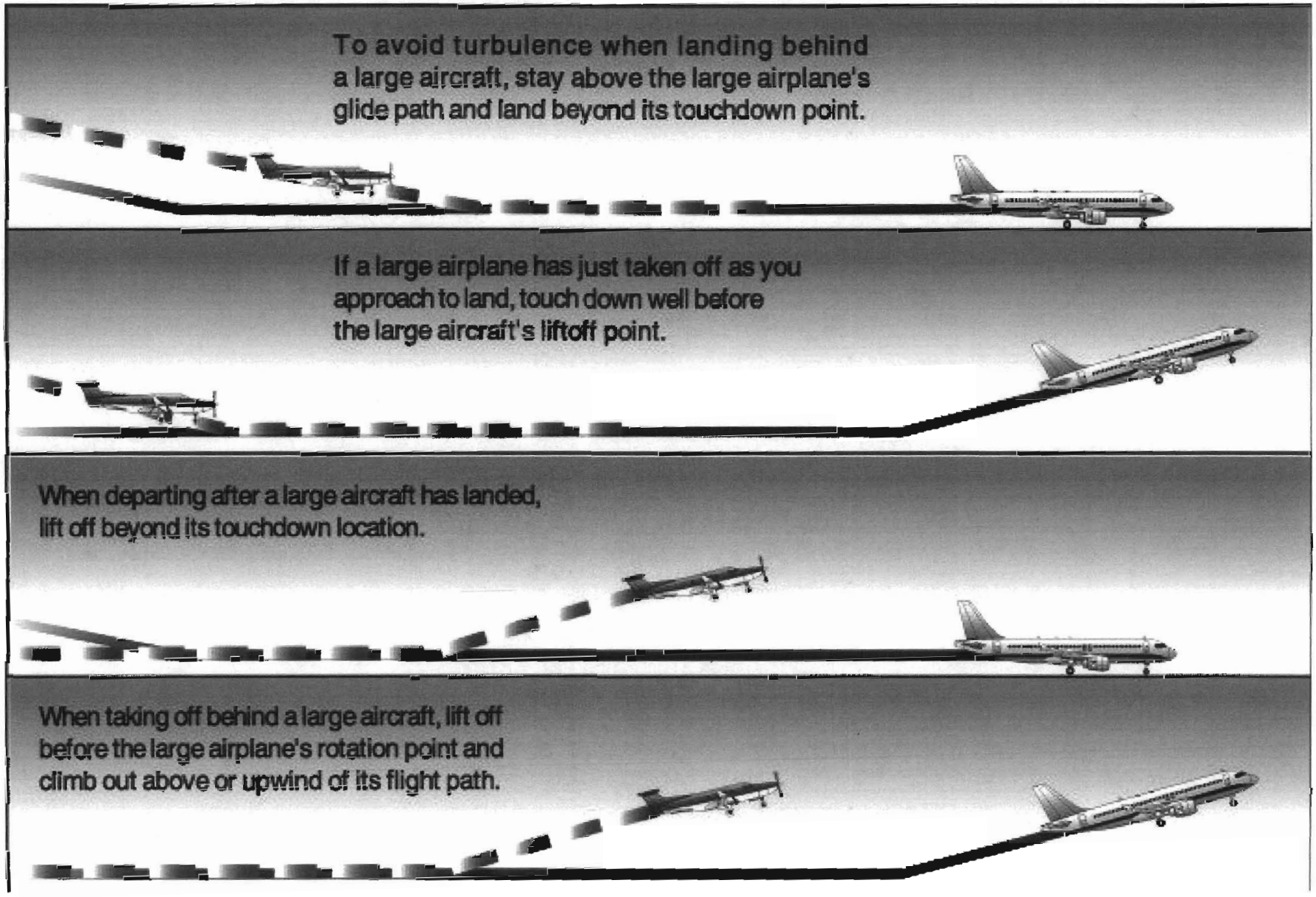
- Descend at a rate of 400 – 500 fpm
- Level off at about 900 ft. below flight path
- Move outward at a rate of 3 kts



Crosswind

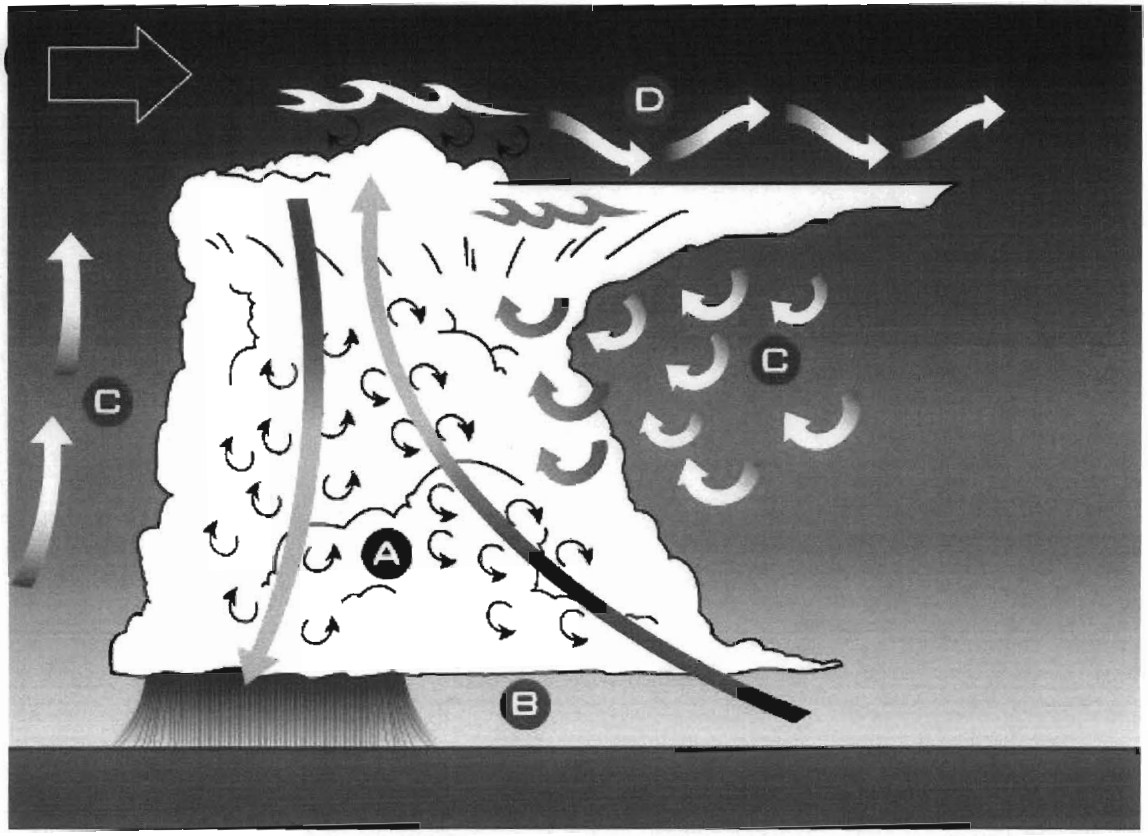


Wake Turbulence Avoidance



Turbulence Near Thunderstorms (TNT)

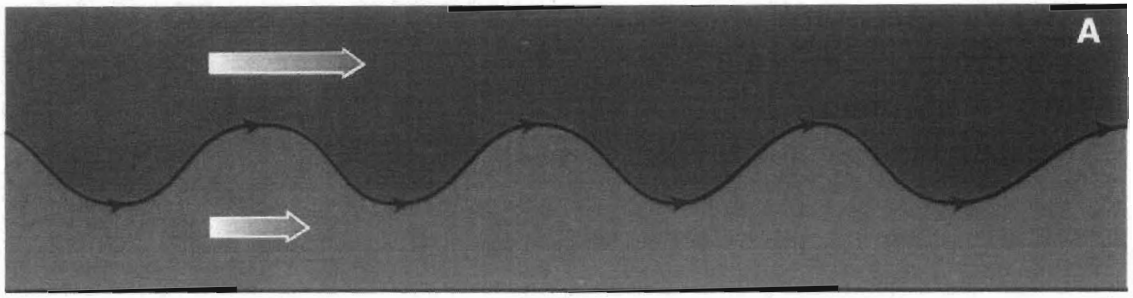
- Most intense and frequent TNT is found within

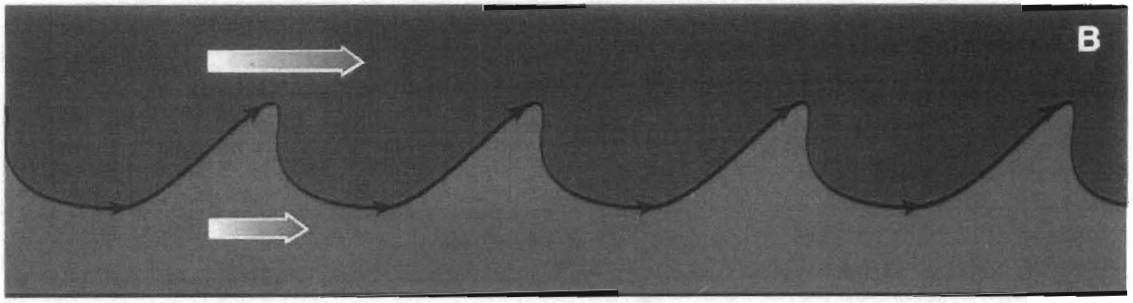


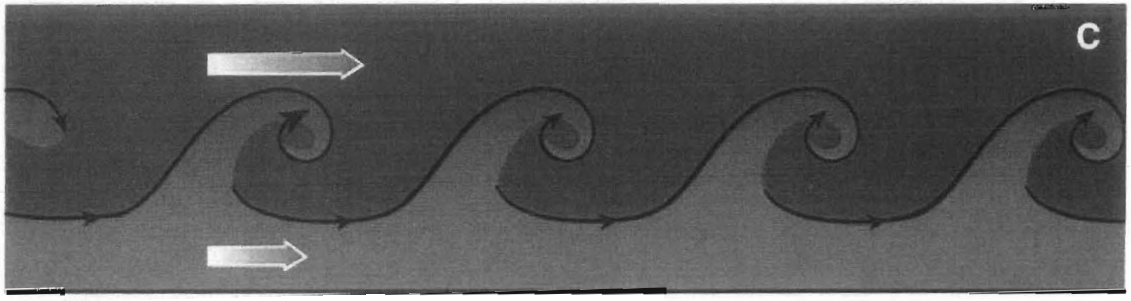
Clear Air Turbulence (CAT)

- Forms away from visible convective activity
- Typically above 15,000 MSL

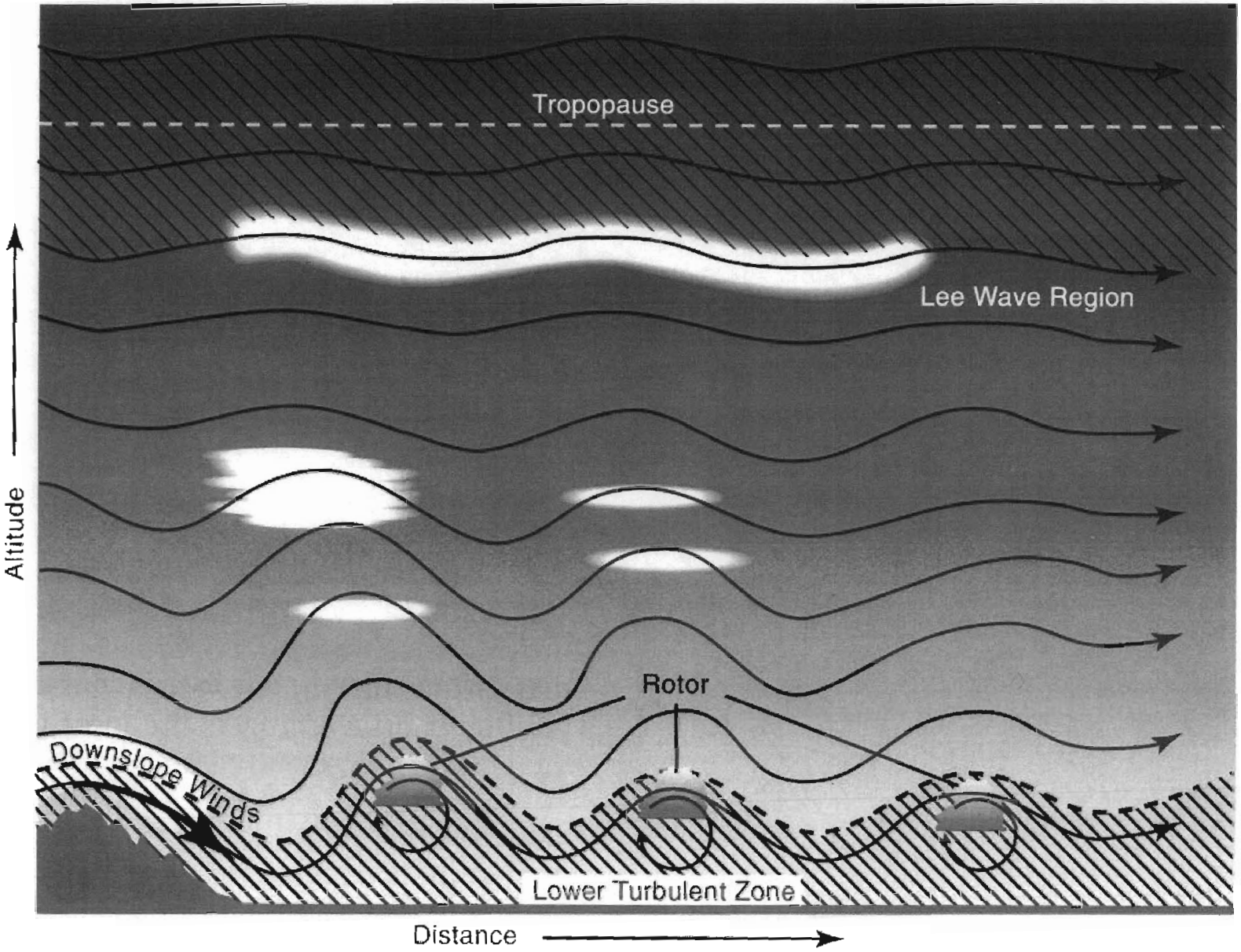
Kitty Clouds







Mountain Wave Turbulence



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Revised 7/15/2005

BLYTHE ENERGY PROJECT II
APPLICATION FOR CERTIFICATION
DOCKET NO. 02-AFC-1

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I declare that on **July 27, 2005**, I transmitted via e-mail of the attached **"Energy Commission Staff's List of Exhibits and Additional Conditions of**

Certification." I declare under penalty of perjury that the foregoing is true and correct.

CHESTER HONG
Legal Secretary

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE STATE OF CALIFORNIA

APPLICATION FOR CERTIFICATION FOR THE BLYTHE ENERGY PROJECT PHASE II	**DOCKET NO. 02-AFC-1** ***(REVISED 7/01/05)***

PROOF OF SERVICE

I, **Chester Hong**, declare that on **July 27, 2005**, I deposited copies of the attached **"Energy Commission Staff's List of Exhibits and Additional Conditions of Certification"** in the United States mail at *Sacramento, CA* with first class postage thereon fully prepaid and addressed to the following:

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Send original and required 12 copies to:

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DOCKET UNIT, MS-4
Attn: Docket No. 02-AFC-1
1516 Ninth Street
Sacramento, CA 95814-5512

In addition to the documents sent to the Commission Docket Unit, also send individual copies of any documents to:

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**Revisions to POS List, i.e. updates, additions and/or deletions.*

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I declare under penalty of perjury that the foregoing is true and correct

[signature]

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* * * *

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