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ABSTRACT

The document is a programed text for a correspondence course in the planning, construction, and maintenance of military roads and airfields. There are seven lessons: construction requirements and design criteria; road reconnaissance and site selection; airfield reconnaissance and site selection; layout procedures, construction staking, and field methods of alinement; expedient methods of earthwork computation; drainage; and earthwork operations and expedient surfaces. Each lesson begins with a list of objectives and ends with a self-test. Answers to the self-tests are given at the end of the book. (PR)

ENGINEER
SUBCOURSE 64-9

ROADS AND AIRFIELDS I

(PROGRAMED INSTRUCTION)

CORRESPONDENCE COURSE PROGRAM

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

EDITION 9 (AUGUST 1974)

INTRODUCTION

CONTENTS

This subcourse provides information used in planning, constructing, and maintaining military roads and airfields. Such information will enable you to better understand and apply the techniques and methods required, and will increase your capability of assuming greater responsibilities.

The subcourse consists of seven lessons and an examination as follows:

Twelve credit hours are allowed for the subcourse.

PRESENTATION

This subcourse is **programed.** Test results prove that for certain subjects this technique is more effective than conventional texts; the method is particularly well suited for correspondence courses.

Essentially, programed instruction is the presentation of ideas in a logically sound learning sequence. It presents material in small bits; it provides cues to the right answer; it often repeats key ideas in a different form or context; and it reinforces immediately the student's correct response.

DESCRIPTION OF MATERIAL

Textual material is divided into **frames** and **panels.** A **frame** presents a single teaching point in a short paragraph, which requires the student to participate in the statement of concept or the answer to the specific problem. A **panel** is an illustration, a table, or other reference material used by the student in solving problems presented by one or more frames.

HOW TO STUDY

Proceed from frame to frame in numerical order. First, read frame 1-1, filling in the blanks in pencil with the appropriate word(s), numerial quantities, or in some instances formulas, as pertinent. **Your writing down the correct answer is an important aspect of the teaching technique.** Then, turn to frame 1-2 and check your written response against the correct answer just above the frame. If your response is correct, proceed with frame 1-2. If not, restudy, the frame, erasing your incorrect response and writing the correct answer in the blank(s).

When the **frame** refers to a **panel**, turn to the panel for the answer needed to fill in the blank(s) correctly. Panels are located after the frames for each lesson.

You will be surprised at how easily you learn to follow the technique and how simple it is to solve the problems.

SELF TESTS

Self Tests are located at the end of each lesson. Work the Self Tests using the reference given with each exercise if necessary. After completing a lesson Self Test, check your answers with the solutions given at the end of the book. Completion of the Self Tests will reinforce your comprehension of the subject.

EXAMINATION

You will not be limited as to the number of hours you may spend on the subcourse, any lesson, or the examination. For statistical purposes, you are required to enter in the proper space on the answer sheet the number of hours spent on the examination.

As soon as you feel ready to take the examination, send the request card to the U. S. Army Engineer School. The grade that you receive on the examination is your grade for the subcourse.

LESSON 1

CONSTRUCTION REQUIREMENTS AND DESIGN CRITERIA

CREDIT HOURS ---------1

TEXT ASSIGNMENT ------Attached memorandum.

LESSON OBJECTIVES

Upon completion of this lesson, you should in each of the following subjects, be able to:

1. **General concepts** – explain the basic concepts behind T.O. construction of roads and airfields to include simplicity of design, economy of time, proper management and the six principal tasks in road and airfield construction.
2. **Roads** – identify road nomenclature and cite military road specifications for the various characteristics.
3. **Airfields** – identify components and cite design criteria for TO Army airfields, determine runway lengths making the necessary corrections for factors requiring corrections, and name the type facility required for the various operational and maintenance needs.
4. **Heliports** – cite the geometric requirements for heliports with taxi-hoverlanes and with runways and give the design criteria for TO heliports.

CONTENTS

ATTACHED MEMORANDUM

Set 1. General Concepts

Frames 1-1 through 1-11 are at top of odd numbered pages.

FRAME 1-1.

Most military operations depend on using certain roads or airfields. The need for them is usually critical and the time element most important. Simple designs requiring a minimum of skilled labor and utilizing available materials, a principle of theater of operations (TO) construction, save **time**. Normally, the nearer the required road or airfield is to the front, the more vital the ________________ element becomes.

---

6 (1-11)

FRAME 1-12.

The roadbed is the traveled way plus the shoulders. The minimum width of roadbed constructed for a two-lane road would be ____________________ feet.

10 (1-22)

FRAME 1-23.

Airfields are designed to accommodate the critical aircraft using them; that is, the aircraft requiring the longest runway, the strongest base course, the lowest glide angle, and so on. For example, the critical Army aircraft to use a certain airfield in a support area, will require a runway at least ________________ feet long.

---

(1) 8 (2) 2 (1-33)

FRAME 1-34.

Every Army landing field requires certain facilities for operation and maintenance. Operational facilities are those required for direct support of aircraft operations (landing, takeoff, and in-flight control). Maintenance facilities are those required for ________________ support.

(time) (1-1)

FRAME 1-2.

Time is saved by **sound planning** and by skillful management of manpower, equipment, and construction materials. Having the necessary dump trucks available as needed is an example of management; building a road to the simplest design practicable is an example of ________ ________.

31 (1-12)

FRAME 1-13.

The subgrade is the natural ground or fill upon which roads and airfields are built. The surface is a wearing course. The layer between subgrade and surface is of compacted materials that support the loads; it is called ________ course.

(3000) (1-23)

FRAME 1-24.

The surface of the support type runway discussed in the previous frame would be constructed of portable materials, probably landing mat. The runway grade would have to provide a minimum sight distance of one-half the runway length plus ______________________ feet.

(indirect) (1-34)

FRAME 1-35.

The control tower, runway lights, and the flight operations tent or building would be examples of the operational facilities (direct support). Hangers and fuel storage structures would be examples of ______________ facilities (indirect support).

(sound) (planning) (1-2)

FRAME 1-3.

The location of roads and airfields depends on the military necessity. However, dense forest and rough terrain require extensive clearing and earthmoving, while use of **existing** facilities usually saves time. If the military situation permits, good planning generally means maximum use of ________________ facilities.

(base) (1-13)

FRAME 1-14.

The stopping sight distance (SSD) is the longest distance in which a driver, whose eyes are 4.5 feet above the road surface, can see an object 4 inches high on the road. Absolute minimum SSD is ____________________ feet.

500 (1-24)

FRAME 1-25.

The runway for a rear area Army airfield must be at least (1) __________ feet wide. The transverse grade should be at least (2) __________ percent and no more than (3) __________ percent.

(maintenance) (1-35)

FRAME 1-36.

Three types of support facilities are installed at Army airfields in the theater of operations — field, intermediate and temporary — depending on the situation. These classes do not necessarily correspond to the three design categories — forward, support, and rear. Panel 1-6 is applicable to frames 1-36 through 1-38. Note, for example, that the structure used for a flight operations center for field and intermediate support facilities is a __________.

(existing) (1-3)

FRAME 1-4.

Safety and **durability** are less important in military construction than in civilian construction. Safety factors are low in keeping with the inherent risks of war. The degree of permanence required in any military road or airfield is relatively small; construction specifications, therefore, usually permit a low durability requirement. Critical time can be saved by constructing with minimum qualities of (1) ______________ and (2) ______________.

---

200 (1-14)

FRAME 1-15.

Roads are crowned to drain the surface course. If a graveled traveled way were 23 feet wide, the minimum height of crown would be (1) ________ inches and maximum required would be (2) ______________ inches.

(1) 72 (2) 0.5 (3) 2 (1-25)

FRAME 1-26.

For a support type airfield requiring a 3000-foot runway, the total length of the flightstrip will be ________________ feet.

(tent) (1-36)

FRAME 1-37.

For intermediate facilities, trucks or trailers are used for the lights and transformer vault, the control tower, and the ________________ equipment.

(1) safety (2) durability (1-4)

FRAME 1-5.

Building a road or runway to permit early use while further completion continues is called stage construction. Thus, one lane of a two-lane road is surfaced for its entire length (or in long sections) before the second lane is completed. Constructing and erecting route marking signs (an engineer task) before a road is open to traffic would violate the principal of ______________ construction.

---

(1) $\frac{1}{2}\left(\frac{23}{2}\right) = 5\frac{3}{4}$ (2) $\frac{3}{4}\left(\frac{23}{2}\right) = 8\frac{5}{8}$ (1-15)

FRAME 1-16.

A straight section of road is referred to as a tangent. Grade change in elevation is expressed as a percentage; that is, a 5-foot vertical change in elevation per 100 feet of horizontal length is a 5 percent grade. The normal maximum grade for a tangent is ______________ percent.

3600 (1-26)

FRAME 1-27.

For a support type airfield to be used by 0-1 aircraft only, the approach zone extends, (1) ______________ feet beyond the end of the flightstrip. A glide angle ratio of 1 foot descent every (2) ______________ feet is required.

(communications) (1-37)

FRAME 1-38.

For field construction, maintenance and supply hangers are not provided. For temporary facilities, the structure provided is normally ______________.

(stage) . (1-5)

FRAME 1-6.

Although engineer units are responsible for maintaining military roads, they provide only major maintenance of Army airfields; that is, work beyond the capability of the **using** unit. Minor maintenance of Army airfields, therefore, must be done by units ________________ the installation.

---

10 (1-16)

FRAME 1-17.

Superelevation refers to the slope of a road around a curve; that is, difference in elevation between "outside" and "inside" edges of the traveled way. Maximum superelevation for a 23-foot traveled way would be ____________________ inches.

(1) 500 (2) 20 (1-27)

FRAME 1-28.

A support type Army airfield is to be built for use by OV-1 aircraft. The taxiway must be built at least (1) ________ feet wide, (2) with ________ foot shoulders and (3) ________ foot lateral clearance.

Set 4. Heliports

(prefab) (1-38)

FRAME 1-39.

Panels 1-7 through 1-9 (applicable to frames 1-39 through 1-45) show the layout and design criteria for Army heliports, which are similar to airfields. For support type construction, runways are (1) ________ feet long and (2) ________ feet wide for CH-54 type helicopters.

(using) (1-6)

FRAME 1-7.

There are six principal tasks in road and airfield construction: clearing, grubbing, stripping, earthwork, drainage, and surfacing. Clearing is the removal of timber and surface boulders; stripping is the removal of objectionable top soil. Removal of stumps and roots is called ________________.

$23 \times 1\frac{1}{4} = 28\frac{3}{4}$ (1-17)

FRAME 1-18.

Absolute minimum horizontal curve radius is, of course, the turning radius of the using vehicles. The specified minimum horizontal radius produces a hairpin turn: it is ________________ feet.

(1) 30 (2) 10 (3) 65 (1-28)

FRAME 1-29.

For a rear area type Army airfield the apron length required is (1) ______________ feet, and the apron width required is (2) ______________ feet.

---

(1) 450 (2) 50 (1-39)

FRAME 1-40.

For a support type heliport, the maximum longitudinal grade for the runway is plus or minus (1) ______________ percent, as compared with plus or minus (2) ______________ percent for runways on support type airfields designed for O-1 aircraft.

(grubbing) (1-7)

FRAME 1-8.

Earthwork, commonly known as **grading**, essentially means cutting off high spots and filling in low places to get a grade level enough. It is the most important construction task because the most time and effort are normally required. Since military roads are built on the principle of stage construction, they are planned so that they may be put into emergency service at any stage after ____________ is completed.

---

150 (1-18)

FRAME 1-19.

The elevation difference in a shoulder of a medium width road is __________ inches.

(1) 1920 (2) 270 (1-29)

FRAME 1-30.

Runway length must be adequate for the takeoff ground run (TGR) of the using aircraft. This will, under some conditions, exceed the minimum runway lengths given in Panel 1-4. Panel 1-5 (applicable to frames 1-30 through 1-33) explains the method for determining runway length for different conditions. The runway length is corrected for altitude by increasing the TGR by (1) ______________ percent for each (2) ______________ foot increase in altitude above (3) ______________ feet.

---

(1) 2 (2) 10 (1-40)

FRAME 1-41.

Support type heliport runway shoulders are built (1) ______________ feet wide. Length of overrun provided is (2) ______________ feet; minimum runway lateral clearance is (3) ______________ feet for CH-54 helicopters.

(grading) (1-8).

FRAME 1-9.

The importance of drainage in both design and construction cannot be overemphasized. The drainage system must remove all surface water from operating areas, and remove detrimental ground water. Instead of subsurface drains, which consume time and transportation, surface ditches are normally used to comply with the TO principle of ____________ design to save time.

Set 3. Airfields

$\frac{3}{4} \times 4 = 3$ (1-19)

FRAME 1-20.

Panel 1-3 shows the components of an airfield. Runways, taxiways, aprons, and hardstands normally have a pavement built on a stabilized or compacted subgrade. As in road construction (panel 1-1) airfield pavements include a surface course over a ____________ course of selected materials with high bearing capacity.

(1) 10 (2) 1000 (3) 1000 (1-30)

FRAME 1-31.

Runway length must also be increased as temperature increases. If the TGR is less than 5,000 feet, the runway length must be increased by (1) ______________________ percent for each ten degree increase in temperature above (2) ______________________ degrees.

---

(1) 10 (2) 100 (3) 135 (1-41)

FRAME 1-42.

Taxiways for support type Army heliports to be used by CH-47 helicopters are built (1) ______________________ feet wide with (2) ______________________ foot shoulder width and a minimum of (3) ______________________ feet lateral clearance.

(simple) (1-9)

FRAME 1-10.

Panels 1-1 and 1-2 combine cross sectional and perspective views with the specifications for a military road. By referring to them in study frames 1-10 through 1-19, you will become acquainted with the more important construction requirements for military roads. You learn, for example, that a turnout is required every ________________ mile when building a single-lane road.

(base) (1-20)

FRAME 1-21.

Shoulders and overruns are normally constructed of materials found in place at the worksite; only clearing and obstacle removal are necessary in the approach zones. In the approach zone, (panel 1-3) obstacles extending above the prescribed ________________ angle must be removed.

(1) 4 (2) 59 (1-31)

FRAME 1-32.

Required runway length, based upon aircraft TGR, is further increased by addition of a safety factor. This safety factor is (1) ______________ for rear area airfields and (2) ______________ for support and forward area airfields.

---

(1) 25 (2) 10 (3) 125 (1-42)

FRAME 1-43.

For support type Army heliports designed for OH-6A helicopters, parking pads are (1) ______________ feet in length and (2) ______________ feet in width. Center-to-center spacing of these pads is (3) ______________ feet.

¼ (1-10)

FRAME 1-11.

The **roadway** is the width that includes the roadbed plus cut slopes or fill slopes. Specifications require that an additional ______________ feet be cleared on each side of the roadway.

Turn back to bottom of page 1-3.

(glide) (1-21)

FRAME 1-22.

Depending on the time available and the intended usage, Army airfields are built to one of three design classes: forward, support, and rear. Panel 1-4 (applicable to frames 1-22 through 1-29) is a table showing these airfield design criteria. Note, for example, that minimum width of shoulders for rear area runways is ______________ feet.

Turn back to top of page 1-4.

(1) 1.5 (2) 1.25 (1-32)

FRAME 1-33.

The term "effective gradient" means the maximum difference in elevation along a runway, divided by the length of the runway, and is expressed in percentage. If the effective gradient of a runway exceeds two percent, the runway length must be increased by (1) ____________ percent for each one percent it exceeds (2) ____________ percent.

Turn back to bottom of page 1-4.

---

(1) 12 (2) 12 (3) 55 (1-43)

FRAME 1-44.

For all type of heliports, the minimum length of the approach-departure zone is (1) ____________ feet, and the minimum length of the takeoff safety zone is (2) ____________ feet.

(1) 1500 (2) 500 (1-44)

FRAME 1-45.

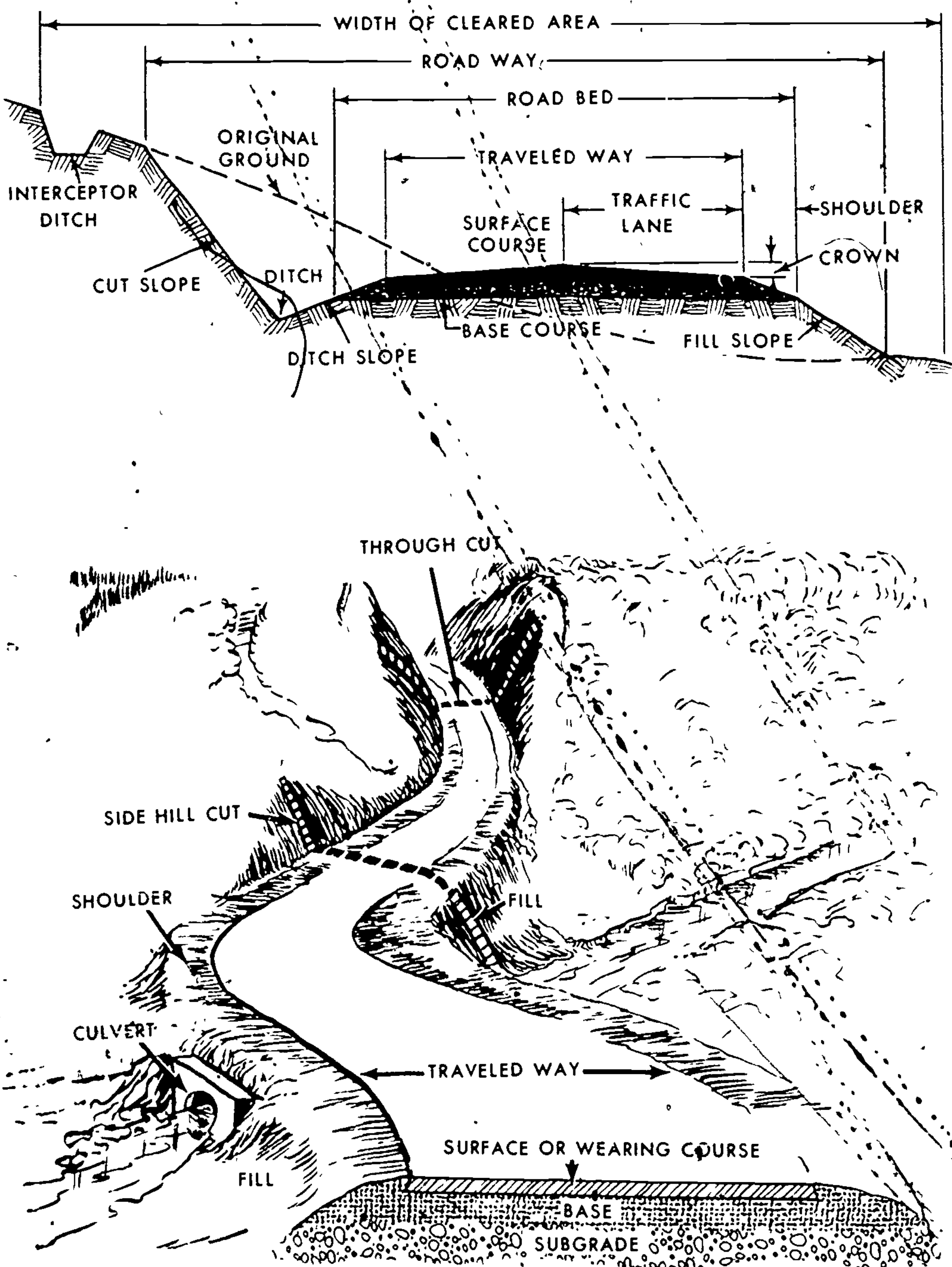
The maximum transverse grade for helicopter taxi hoverlanes is (1) ____________ percent, and the minimum transverese grade for helicopter taxi hoverlanes is (2) ____________ percent.

(1) 5 (2) 1.5 (1-45)

END OF FRAMES

PANELS AND SELF TEST FOLLOW

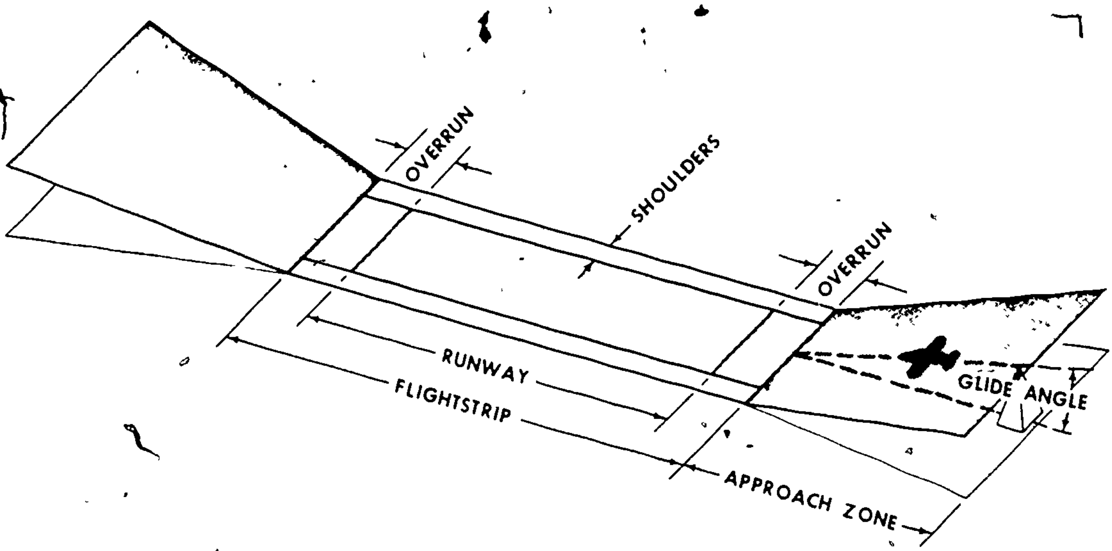
Panel 1-1. Typical cross section and perspective illustrating road nomenclature.

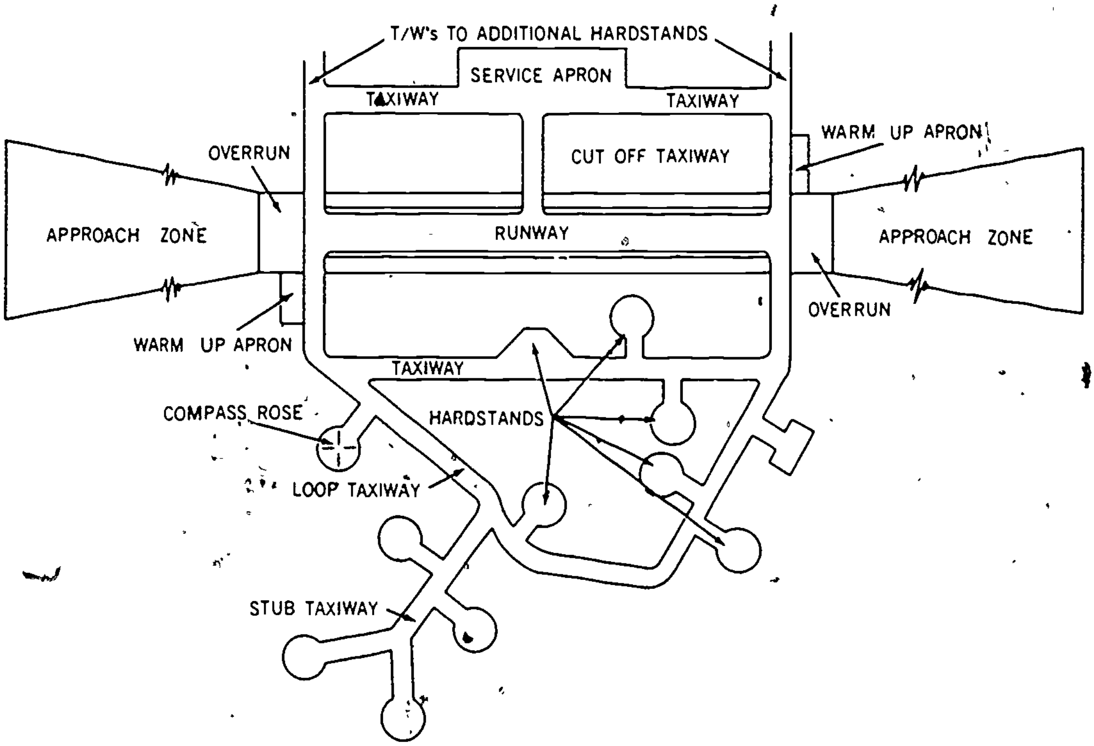


Panel 1-2. Military road specifications.

	Characteristics	Specifications
1.	**WIDTH:**	
	Traveled way (single lane)	Minimum — 11½ feet.
	Traveled way (two lanes)	Minimum — 23 feet.
	Shoulders (each side)	Minimum — 4 feet.
	Clearing	Minimum — 6 feet on each side of roadway.
2.	**ALINEMENT:**	
	Grades:	
	Absolute maximum	Lowest maximum gradability of vehicles for which road is built.
	Normal maximum	10 percent.
	Desirable maximum	Tangents and gentle curves, less than 6 percent; sharp curves, less than 4 percent.
	Horizontal curve radius	Minimum — 150 feet.
	Vertical curve length:	
	Invert curves	100 feet minimum for each 4 percent algebraic difference in grades.
	Overt curves	125 feet minimum for each 4 percent algebraic difference in grades.
	Sight distance:	
	Stopping	Absolute minimum — 200 feet.
	Passing	Absolute minimum — 350 feet.
3.	**LOAD CAPACITY:**	
	Road proper	Sustain design numbers of equivalent 18,000-pound operations/day.
	Bridges	Accommodate using traffic.
4.	**SLOPES:**	
	Shoulders	¾ inch per foot.
	Crown (gravel and dirt)	½ to ¾ inch per foot to ℄.
	Crown (paved)	¼ to ½ inch per foot to ℄.
	Superelevation	¼ to 1¼ inch per foot.
	Cut	Variable.
	Fill	Variable.
5.	**MISCELLANEOUS:**	
	Overhead clearance	Minimum — 14 feet.
	Traffic volume	2,000 vehicles per day.
	Turnouts (single lane)	Minimum — every ¼ mile.

Panel 1-3. Components of an Army airfield.





Panel 1-4. Theater of operations Army airfield design criteria.

Item No.	RUNWAY	FORWARD		SUPPORT		REAR
		0-1	OV-1	0-1	OV-1	0-1/OV-1
1.	Length (minimum)	750′	2500′	1000′	3000′	3000′
2.	Takeoff ground run[1]	390′	2000′	390′	2000′	2000′
3.	Safety factor	1.25	1.25	1.25	1.25	1.50
4.	Width (minimum)	50′	60′	50′	60′	72′
5.	Shoulder width (minimum)	N/A	10′	N/A	10′	10′
6.	Lateral clearance (center line of runway to near edge of taxiway or fixed obstable)	75′	230′	100′	230′	236′
7.	Runway surfacing	Membrane/ landing mat	Membrane/ landing mat	Membrane/ landing mat	Membrane/ landing mat	Membrane/ landing mat
8.	Longitudinal grade (maximum)	± 10%	± 5%	± 10%	± 4%	± 3%
9.	Maximum grade change per 100 ft	2.0%	2.0%	2.0%	1.5%	1.5%
10.	Minimum sight distance across vertical curves (height of eye—5′ to a point 5′ above runway surface)	½ runway length	½ runway length	500′ + ½ runway length	500′ + ½ runway length	500′ + ½ runway length

O-1 Aircraft in liaison category

OV-1 Aircraft in surveillance category

Panel 1-4. Continued.

Item No.	RUNWAY	FORWARD		SUPPORT		REAR
		0-1	OV-1	0-1	OV-1	0-1/OV-1
11.	Minimum distance PI to PI on vertical curves	200′	200′	600′	600′	800′
12.	Transverse grade	5.0%	0.5 - 3.0%	5.0%	0.5 - 3.0%	0.5 - 2.0%
13.	Transverse shoulder grade	N/A	1.5 - 5.0%	N/A	1.5 - 5.0%	1.5 - 5.0%
14.	Parallel runways (minimum spacing; center-to-center)	200′	200′	300′	300′	300′
15.	Cleared areas maximum slope	N/A	5%	N/A	5%	5%
	TAXIWAYS					
16.	Width	N/A	30′	N/A	30′	36′
17.	Shoulder width (minimum)	N/A	10′	N/A	10′	10′
18.	Lateral clearance	N/A	65′	N/A	65′	65′
19.	Longitudinal grade (maximum)	N/A	5%	N/A	5%	5%
20.	Transverse grade	N/A	0.5 - 3.0%	N/A	0.5 - 3.0%	0.5 - 2.0%
21.	Transverse shoulder grade	N/A	1.5 - 5.0%	N/A	1.5 - 5.0%	1.5 - 5.0%
22.	Taxiway turn radii (minimum)	N/A	70′	N/A	70′	70′

Panel 1-4. Continued.

Item No.	RUNWAY	FORWARD		SUPPORT		REAR
		0-1	OV-1	0-1	OV-1	0-1/OV-1
	APRONS					
23.	Number of aircraft	N/A	8	N/A	20	32
24.	Apron length	N/A	600′	N/A	1500′	1920′
25.	Apron width	N/A	120′	N/A	120′	270′
26.	Transverse grade	N/A	1.5 - 5.0%	N/A	1.5 - 5.0%	1.5 - 5.0%
27.	Lateral clearance, apron edge to fixed obstacle	N/A	45′	N/A	50′	50′
28.	Warm-up apron width	N/A	100′	N/A	100′	100′
	OVERRUN					
29.	Length from end of runway	N/A	200′	N/A	300′	300′
30.	Width at end of runway	N/A	60′	N/A	60′	72′
31.	Longitudinal grade (maximum)	N/A	5.0%	N/A	5.0%	5.0%
32.	Transverse grade	N/A	same as runway and shoulders	N/A	same as runway and shoulders	same as runway and shoulders

Panel 1-4. Continued.

Item No.	RUNWAY	FORWARD		SUPPORT		REAR
		0-1	OV-1	0-1	OV-1	0-1/OV-1
	APPROACH ZONE					
33.	Length (from end of flight strip)	500′	1500′	500′	2000′	2,500′
34.	Width (at end of fight-strip)	150′	200′	150′	260′	272′
35.	Width at outer end	500′	1000′	500′	1,500′	1,500
36.	Glide angle (ratio)	15:1	20:1	20:1	30:1	20:1

[1] Runway length shall be computed from takeoff ground run distance, corrected for temperature, altitude, gradient, and safety factor, as indicated in panel 1-5. The computed length, or the minimum runway length as given in line 1, whichever is the greater, will then be used.

Panel 1-5. Runway length determination for airfields in the theater of operations.

1)	TAKEOFF GROUND RUN	Takeoff ground run (TGR) for individual aircraft is shown in panel 1-4.
2)	ALTITUDE CORRECTION	Increase the takeoff ground run (TGR) by +10% for each 1000 ft increase in altitude above 1000 ft.
3)	TEMPERATURE CORRECTION*	Increase the corrected runway length, obtained from the previous computation, by +7% for each 10°F increase in temperature above 59°F, if takeoff ground run is greater than 5000 ft. Increase by 4% per 10° above 59° if takeoff ground run is less than 5000 ft.
4)	SAFETY FACTOR	Multiply the corrected runway length from the previous computation by 1.5 for Rear Area Airfields and 1.25 for Support and Forward Area Airfields.
5)	EFFECTIVE GRADIENT CORRECTION	Increase the corrected runway length, obtained from the previous computation, by +8% for each 1% of effective gradient over 2%. Using the above runway length, the effective gradient can be determined from the profile of the airfield.
6)	ROUND UP	The final runway length will be the takeoff ground run corrected (if required) for conditions of altitude, temperature, safety factor, and effective gradient, and raised to the next larger 100 feet
7)	COMPARE WITH MINIMUM REQUIRED	Compare calculated length obtained from the previous computation with the minimum length required as shown in panel 1-4. Use the greater value.

* The temperature to be considered is the mean temperature for the warmest period during which operations will be conducted from the airfield.

Panel 1-5. Continued.

Illustrative example. The design of a support area, surveillance type airfield has been requested.

The following additional information is supplied.

Altitude of the proposed site	1600 feet
Mean hottest temperature	79°F
The effective gradient	3%

1. Takeoff Ground Run (TGR) = 2000′ (Panel 1-4)

2. Altitude Correction

   $(1600' - 1000') \times \frac{10\%}{1000'} = 6\%$ $1.06 \times 2000 = 2120'$

3. Temperature Correction

   $(79° - 59°) \times \frac{4\%}{10°} = 8\%$ $1.08 \times 2120 = 2290'$

4. Safety Factor $1.25 \times 2290 = 2863'$

5. Effective Gradient

   $(3\% - 2\%) \times \frac{8\%}{1\%} = 8\%$ $1.08 \times 2863 = 3092'$

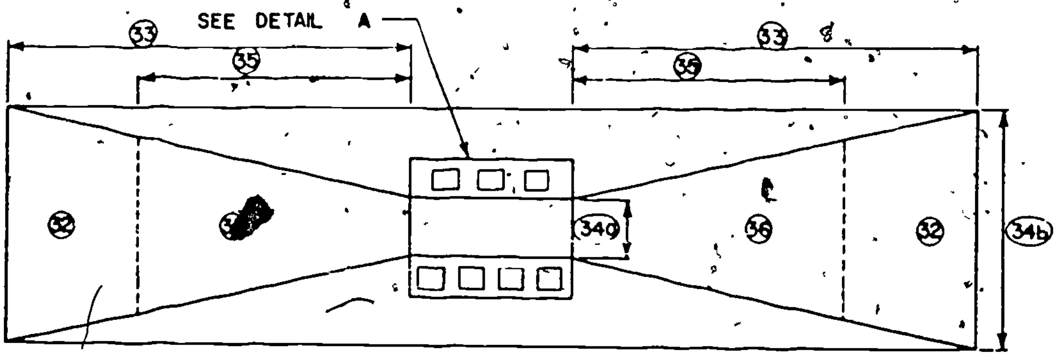
6. Round up **3100′**

7. Check Minimum Req'd (Panel 1-4) = 3000′
   Select 3100′ as appropriate length

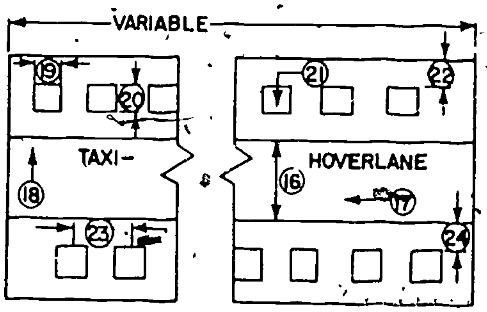
Panel 1-6. Operational and maintenance facilities, Army airfields and heliports.

	Facility	Field	Intermediate	Temporary
1.	Control tower structure	None	Truck or trailer mounted	Frame
2.	Wind indicator	Sock	Sock	Sock
3.	Runway lighting	Laid on ground surface	Laid on ground surface	Laid on ground surface
4.	Navigational aids	Tent	Tent	Frame
5.	Flight operations center	Tent	Tent	Prefab
6.	Communications	Tent	Truck or trailer mounted	Frame
7.	Hangars, maintenance, and supply	None	Tent	Prefab
8.	Storage facilities, unit supply	Tent	Tent	Prefab
9.	Fuel storage	None	None	Fenced area
10.	Fire fighting equipment	None	Tent	Prefab
11.	Runway marking	Laid on ground surface	Laid on ground surface	Laid on ground surface
12.	Personnel messes and quarters	Tent	Tent	Prefab
13.	Cargo handling facilities	None	Tent	Prefab
14.	Airfield lighting and transformer vault	Lean - to	Trailer mounted	Shed

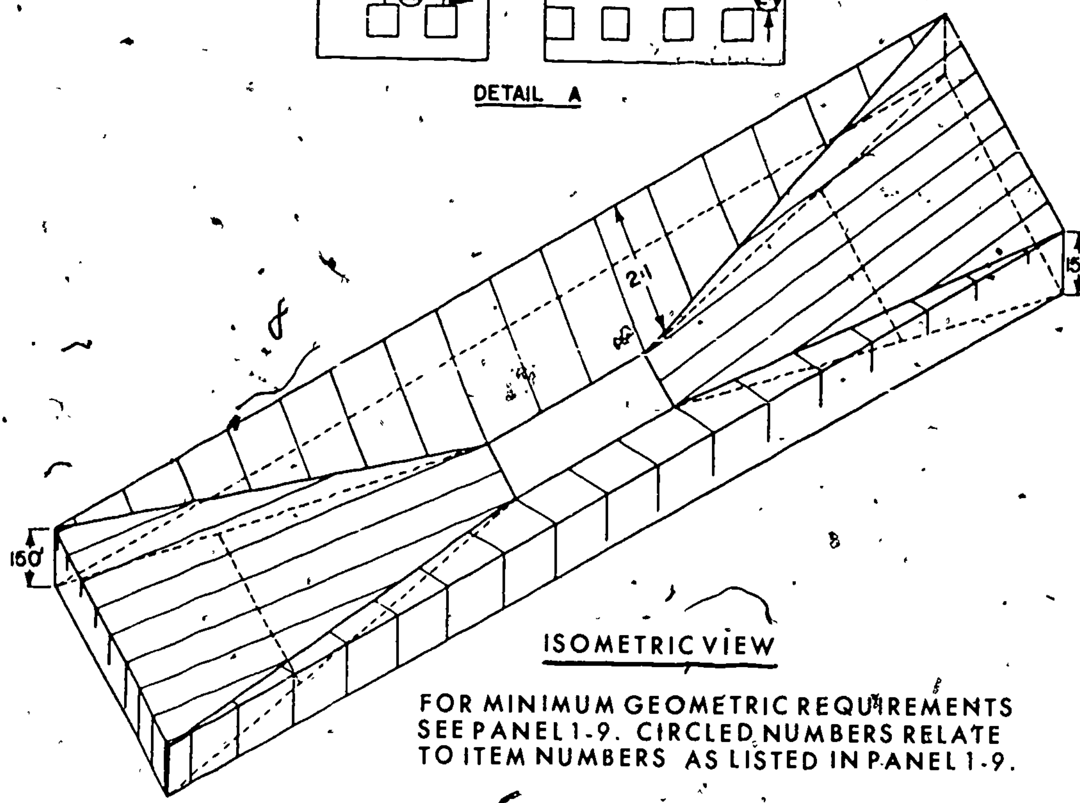
Panel 1-7. Geometric requirements for heliports with taxi-hoverlanes.



PLAN



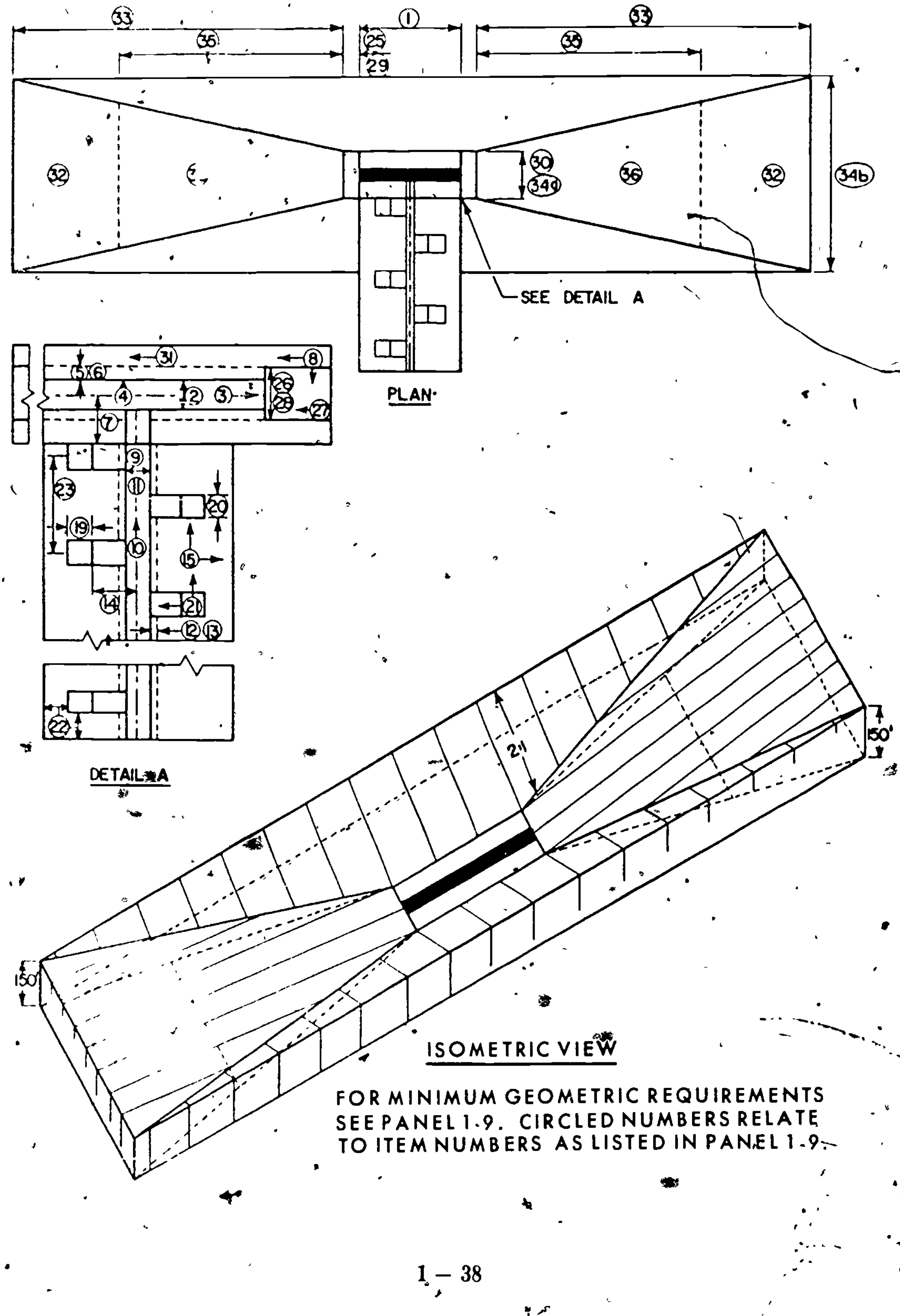
DETAIL A



ISOMETRIC VIEW

FOR MINIMUM GEOMETRIC REQUIREMENTS SEE PANEL 1-9. CIRCLED NUMBERS RELATE TO ITEM NUMBERS AS LISTED IN PANEL 1-9.

Panel 1-8. Geometric requirements for heliports with runways.



FOR MINIMUM GEOMETRIC REQUIREMENTS SEE PANEL 1-9. CIRCLED NUMBERS RELATE TO ITEM NUMBERS AS LISTED IN PANEL 1-9.

Panel 1-9. Theater of operations Army heliport design criteria.

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
	Heliport runways												
1	Length, ft[1]	—	—	—	—	—	—	450	450	—	—	450	450
2	Width, ft	—	—	—	—	—	—	25	50	—	—	40	60
3	Longitudinal grade of runways and shoulders, %	—	—	—	—	—	—	±2	±2	—	—	±2	±2
4	Transverse grade of runway, %												
	max	—	—	—	—	—	—	1.5	1.5	—	—	1.5	1.5
	min	—	—	—	—	—	—	.5	.5	—	—	.5	.5
5	Shoulder width, ft	—	—	—	—	—	—	10	10	—	—	25	25
6	Transverse grade of shoulders, %												
	max	—	—	—	—	—	—	3	3	—	—	3	3
	min	—	—	—	—	—	—	2	2	—	—	2	2
7	Clearance from runway ℄ to fixed and/or movable obstacles, ft	—	—	—	—	—	—	125	135	—	—	125	135
8	Cleared areas, slope, % max	—	—	—	—	—	—	5	5	—	—	5	5

[1] Where runway length is not shown, takeoff and landing is on taxi-hoverlane.

Panel 1-9. Continued.

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
	Heliport taxiways												
9	Width, ft	—	—	—	—	—	—	25	40	—	—	40	60
10	Longitudinal grades of taxiways and shoulders, %	—	—	—	—	—	—	2	2	—	—	2	2
11	Transverse grade of taxiway, %												
	max	—	—	—	—	—	—	1.5	1.5	—	—	1.5	1.5
	min	—	—	—	—	—	—	.5	.5	—	—	.5	.5
12	Shoulder width, ft	—	—	—	—	—	—	10	10	—	—	25	25
13	Transverse grades of taxiway shoulders, %												
	max	—	—	—	—	—	—	3	3	—	—	3	3
	min	—	—	—	—	—	—	2	2	—	—	2	2
14	Clearance from taxiway ℄ to fixed and/or movable obstacles, ft	—	—	—	—	—	—	125	135	—	—	125	135
15	Grade in any direction in taxiway cleared area, %	—	—	—	—	—	—	5	5	—	—	5	5
	Taxi-hoverlane												
16	Width ft[2]	75	140	180	200	100	200	240	250	100	200	240	250

[2] Taxi-Hoverlane is used for takeoff and landing where provided.

Panel 1-9. Continued.

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
	Taxi-hoverlane (continued)												
17	Longitudinal grade of Taxi-hoverlane, % max	10	10	10	10	5	5	5	5	5	5	5	5
18	Transverse grade of Taxi-hoverlane, % max	5	5	5	5	5	5	5	5	5	5	5	5
	min	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Heliport parking pad												
19	Length, ft	12	20	50	50	12	20	50	50	25	40	50	100
20	Width, ft	12	20	25	50	12	20	25	50	25	40	100	100
21	Parking pad grade in any direction, % max	3	3	3	3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	min	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
22	Lateral clearance from rear and sides of parking pad to fixed and/or movable obstacles except other aircraft, ft	25	45	65	55	25	55	75	65	30	65	100	95
23	C-C spacing of parking pads, ft	40	75	150	150	55	80	175	175	55	80	175	175

Panel 1-9. Continued.

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
	Heliport parking pad (continued)												
24	Spacing from edge of Taxi-hoverlane to edge of parking pad, ft	10	20	20	20	10	20	20	20	10	20	20	20
	Heliport overrun												
25	Length, ft	—	—	—	—	—	—	100	100	—	—	100	100
26	Width, ft	—	—	—	—	—	—	Same as runway plus shoulders					
27	Longitudinal grade, %	—	—	—	—	—	—	2	2	—	—	2	2
28	Transverse grade, %												
	max	—	—	—	—	—	—	3	3	—	—	3	3
	min	—	—	—	—	—	—	2	2	—	—	2	2
	Heliport clear zone												
29	Length, ft	—	—	—	—	—	—	100	100	—	—	100	100
30	Width, ft	—	—	—	—	—	—	250	270	—	—	250	270
31	Grades outside of overrun and shoulders, %	—	—	—	—	—	—	5	5	—	—	5	5
	Heliport approach-departure zone												
32	Approach-departure surface ratio	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1

Panel 1-9. Continued

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
	Heliport approach-departure zone (continued)												
33	Length, ft	1500	1500	1500	1500	1500	1500	1500	1500	[illegible]	1500	1500	1500
34	Width, ft at end of clear zone or Taxi-hoverlane	75	140	180	200	100	200	250	270	100	200	250	270
	at outer end	850	850	850	850	850	850	850	850	850	850	850	850
	Heliport takeoff safety zone												
35	Length, ft	500	500	500	500	500	500	500	500	500	500	500	500
36	Width, ft	Same as approach-departure zone											
	Service roads												
37	Width, ft[1]	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	23	23	23	23

[1] Roads should be located so as to require the least engineer effort.

LESSON 1

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

1. Discuss the responsibility of engineer units and the using unit with respect to maintenance of Army airfields. (frame 1-6)

2. Outline the six principal tasks in road and airfield construction giving a short explanation of each. (frame 1-7, 1-8)

3. Make a sketch showing the relationship of the wearing surface, base, and subgrade. (panel 1-1)

4. Maximum superelevation for a 23-foot traveled way is 28.7 inches. What is meant by superelevation? (frame 1-17)

5. Give the minimum widths of the traveled way, shoulders, and clearing. (panel 1-2)

6. Describe the specifications for normal maximum and desirable maximum grades. (panel 1-2)

7. Tell how the invert vertical curve compares with the overt vertical curve with respect to curve length. (panel 1-2)

8. Give the specifications of the slopes of a road with a paved crown. (panel 1-2)

9. Where is the overrun situated with respect to the runway and approach zone? (panel 1-3)

10. Support your choice of one of the following alternatives for a road approximately seven miles long:

a. construction through relatively flat, wooded area

b. rehabilitating an existing dirt road

c. building a straight-line route over whatever obstacles exist

d. constructing over hilly, treeless terrain (frame 1-3)

11. The tactical situation requires the construction of a single-lane road, two miles in length. What is the minimum number of turnouts that should be provided to permit use of the road in both directions? (frame 1-10 and panel 1-2)

12. The minimum runway length required for the critical aircraft to use a rear Army airfield is 3000 feet. The runway plus overruns will have to be how many feet long? (frame 1-23 and panels 1-3 and 1-4)

13. The takeoff ground run for an OV-1 aircraft is 2,000 feet. If the airfield is to be at 3,000 feet altitude, and the mean hottest temperature will be 69°F., what will be the required runway length when corrections are made for altitude and temperature only? (frames 1-30, 1-31 and panel 1-5)

14. Corrections are also made to include a safety factor and for the effective runway gradient. If the runway described in the preceding exercise is in a rear area, and the effective gradient is 3%, what will the final corrected runway length be, rounded off to the next larger 100 feet? (frame 1-32, 1-33 and panel 1-5)

15. What is the length of a support Army heliport runway plus overruns? (frame 1-39 and panels 1-7, 1-8, 1-9)

16. What is the minimum width, in feet, for a service road for a heliport in a forward area? (panel 1-9)

LESSON 2

RECONNAISSANCE AND LOCATION OF ROADS

CREDIT HOURS 1

TEXT ASSIGNMENT .... Attached Memorandum.

LESSON OBJECTIVES

Upon completion of this lesson, you will be able, in the following subject areas to:

1. **General principles of reconnaissance** — Explain the purposes of a general reconnaissance and a road reconnaissance; discuss the following as pertaining to a location reconnaissance: topography, soil bearing capacity, stability, drainage, use of a geologist, ~~the four~~ considerations of rock formation, and the two methods used to determine road location.
2. **Hasty location methods** — Discuss hasty location considerations, the use of maps and aerial photos, and the instruments needed to apply these methods (magnetic compass, hand level, metallic tape, and clinometer).
3. **Deliberate location methods** — Give the definition of deliberate location methods; describe the planning process to include the use of control points, the further subdivision into primary, intermediate, and secondary control features, alternate plans, and ground reconnaissance.
4. **Final location** — Describe the process by which final location is chosen explaining the use of the preliminary survey which utilizes terrain features, tentative center line, soil classification, and maps to arrive at the final location; also the two methods used to actually set the final location of the road.

CONTENTS

Set 1. General Principles of Reconnaissance

FRAME 2-1.

The purpose of reconnaissance is to determine the best possible route for a specific military need. The tactical commander must have vehicular mobility between certain points. The engineer must find the most practical route to meet that tactical requirement; that is, one which will require the least cost in man-hours, equipment, and construction materials. He makes a ________________ to determine the most ________________ route.

(alinement) (2-12)

FRAME 2-13.

The bearing capacity, stability, and drainage characteristics of soils are important considerations. The organic soils of a swampy area are the most difficult to drain and have the poorest bearing capacity. Excessive engineer effort and possible road failure can normally be avoided when the types of ____________ are accurately identified during a location reconnaissance.

(hasty) (location) (2-24)

FRAME 2-25.

Hasty location made from a study of maps and aerial photographs, is supplemented by **ground** reconnaissance. The ________________ reconnaissance is made by riding or walking over the ground; sometimes portions of a route can be located by observation from a high point of ground.

Set 4. Final Location

(map) (2-36)

FRAME 2-37.

Usually, a preliminary survey (panel 2-3) is essential to the selection of a final location for the proposed road. In addition to the plotting of terrain features, a tentative ________________ is established, critical ________________ are plotted, and the ________________ encountered are classified.

(reconnaissance) (practical) (2-1)

FRAME 2-2.

In a tactical situation, the engineer is rarely concerned with the dollar cost of the road he constructs. Other assets, however, must be considered because they are always in short supply for example, **man-hours**. The engineer must get his work done with maximum savings in __________ - __________, equipment, and construction materials.

(soils) (2-13)

FRAME 2-14.

Natural drainage is usually good drainage. Locating a road to take advantage of **natural drainage** also reduces the construction effort required. Long stretches of flat ground often drain poorly. Locating a road along ridges and stream lines usually takes best advantage of __________ __________.

(ground) (2-25)

FRAME 2-26.

Frequently hasty location occurs **simultaneously** with construction operations. The engineer in charge may have a map in one hand while indicating the road alinement to equipment operators with the other. In keeping with tactical time limitations, construction operations are often conducted ______________ with the hasty location of a road.

(centerline) (elevations) (soils) (2-37)

FRAME 2-38.

Frames 2-38 through 2-40 are also based on panel 2-3. Of particular importance are those terrain features which influence the location of the ____________, and the determination of sufficient ______________ ______________, necessary for ______________ estimates.

(man-hours) (2-2)

FRAME 2-3.

All phases of new road construction require great amounts of engineer effort —particularly clearing, drainage, and earthwork. Therefore, existing roads can usually be repaired and improved far more economically than new roads can be built because the heavy initial work is already done. The first purpose of reconnaissance is to find ____________ roads that can be made to meet the tactical need.

(natural) (drainage) (2-14)

FRAME 2-15.

A geologist's advise on **ground-water** tables is especially useful in location reconnaissance. It is also needed in determining effects of any rock formations: essentially to avoid extensive blasting work on cut and fill operations and the danger of landslides and rock falls, particularly where clay or shale layers are present. Some knowledge of geology helps in identifying troublesome rock formations and high ____________ - ____________ tables.

(simultaneously) (2-26)

FRAME 2-27.

A magnetic compass, hand level or clinometer, and metallic tape are the only surveying instruments normally used in establishing a ________________ location. These instruments are useful in obtaining data concerning alinement and grades.

(centerline) (cross sections) (earthworth) (2-38)

FRAME 2-39.

All pertinent data is plotted on a ________________ which is drawn to summarize the preliminary survey. Soil classification data at ________________ ________________ are included on the map.

(existing) (2-3)

FRAME 2-4.

A road reconnaissance is made to obtain information about existing roads, primarily for immediate use and establishment of a route. It may include estimates of the practicability of improvement, and the engineer work in conditioning a road to accommodate specified traffic and loads. DA Form 1248 (panel 2-1) is used to report the information obtained. This type of reconnaissance is called ________ reconnaissance and is limited to ________________ roads.

(ground-water) (2-15)

FRAME 2-16.

Rock formations are also important considerations in location reconnaissance as possible natural foundations or as possible quarry sites for construction materials (fill, base course, and surface course). When rock formations are used as a foundation, drainage problems and possible failure in localities of cavernous limestone are possible. There are four considerations concerning rock formations which should be noted in location reconnaissance: (1) Suitability as natural foundations, (2) possible quarry sites, (3) ______________-______________ tables, and (4) excessive ________________ work.

(hasty) (2-27)

FRAME 2-28.

Consistent with __________ requirements, hasty location is governed by the character of the soil and topography which will require the least construction effort for __________ and grading.

(map) (typical) (locations) (2-39)

FRAME 2-40.

The degree of accuracy with which the __________ survey is conducted is determined by the given situation. In the final analysis, however, its accuracy will influence the extent of the __________ survey.

(road) (existing) (2-4)

FRAME 2-5.

A road is no better than its worst obstruction. Logical procedure for improving existing roads, therefore, is to reduce the most limiting bottlenecks first. Obstructions noted during road reconnaissance are reported in Section III of DA Form 1248. For example, the grid references for grades steeper than ________ percent are reported.

---

(3) ground-water (4) blasting (2-16)

FRAME. 2-17.

Water is necessary for construction work as well as for personnel. The quantity, quality, and accessibility of ________________ sources should always be determined in a location reconnaissance.

(tactical) (drainage) (2-28)

FRAME 2-29.

Deliberate location is the careful selection of the best route for a road. It is usually confined to rear areas and the construction of main supply roads. ________ location is based on an engineer study including evaluation of several possible routes in terms of design standards and location criteria.

(preliminary) (final) (2-40)

FRAME 2-41.

From the data secured in the preliminary survey, a final specific location must be selected for the new road. This entire operation is called ______________ ______________.

7 (2-5)

FRAME 2-6.

Section II of DA Form 1248 provides for detailed information on alinement, drainage, foundation, and road surface. The back (Section IV) of the form provides a detailed ________________ ________________.

(water) (2-17)

FRAME 2-18.

Vegetation affecting **clearing** and **grubbing** work is noted during location reconnaissance. This is termed timber cruising. Also, the effects of clearing on camouflage and availability of timber for construction may be significant. Timber cruising is the reconnaissance activity that estimates the amount of __________ and ____________ involved.

(deliberate) (2-29)

FRAME 2-30.

In planning deliberate location of a road, the **control points** (locations or conditions which more or less dictate the trace of the road) are identified. Naturally, the terminal points and the intermediate points through which the road must pass are primary ________________ ________________.

(final) (location) (2-41)

FRAME 2-42.

Final location is based on an **evaluation** (weighing) of the elements of **alinement, grade,** and **earthwork** involved in the proposed location. These factors would be ________________ to find the most practical route for construction.

(mileage) (chart) (2-6)

FRAME 2-7.

The purpose of **periodic** road reconnaissance is to maintain complete data on the condition of roads currently in use. The information obtained is normally posted on a situation map. To insure that roads are **NOT** maintained longer than needed, maintenance requirements based on ________________ road reconnaissance are coordinated with the principal users.

(clearing) (grubbing) (2-18)

FRAME 2-19.

Ease of future **maintenance** is a factor. In areas of rain or snow, locating the road on the sunny side of slopes and canyons minimizes the possibility of the road's becoming impassible for long periods and eases ____________ work.

(control) (points) (2-30)

FRAME 2-31.

Impassible lakes or swamps are also classed as ________________ control points. Deep organic soils in marshy areas should also be noted because roads built in such locations take extraordinary effort and are likely to fail. Once these features are located, the engineer may sketch or visualize the most direct remaining route between the essential terminals and intermediate points.

(weighed or evaluated) (2-42)

FRAME 2-43.

All tangents and curves involved in the horizontal positioning of the road are considerations of ________________; the rates of changes (elevations) involved in the vertical positioning profile of the road are considerations of ________________; and the extent of cuts and fills to be made are considerations of ________________.

(periodic) (2-7)

FRAME 2-8.

In active military operations, new road construction is avoided whenever possible, and in all cases it is held to the necessary minimum. If determining the location of a new road is involved, the specific term is **location** reconnaissance. Only after the possibility of using an existing road has been eliminated, is the construction of a new road undertaken. When a new road is determined to be necessary, the first step is ________________ reconnaissance.

(maintenance) (2-19)

FRAME 2-20.

At times, **tactical** and engineering considerations are in conflict with the best location based on the preceding criteria. In these cases, the location criteria must be subordinated. An overriding ________________ consideration, for example, is that the road must be ready for use when the situation requires it. Improvements may be effected at a later date.

(primary) (intermediate) (2-31)

FRAME 2-32.

Secondary control features are those which present the most likely places for the road and which avoid difficult construction. Saddles or gaps which permit crossings between ridges and river-crossing points are examples of ____________ control features. Where a road can follow general contour directions, construction is usually easier. Such sections become tertiary control features.

(alinement) (grade) (earthwork) (2-43)

FRAME 2-44.

Two methods are employed in final location — **field location** and **paper location.** Working out the location of the road on the ground, using the preliminary survey alinement and profile as a basis for development would be ____________ ____________.

(location) (2-8)

FRAME 2-9.

Location reconnaissance has as its main objective that location of a new road that will hold up under anticipated traffic and provide optimum operating conditions with a judicious expenditure of engineer effort. Several location criteria are followed as closely as possible during (1) ________________ reconnaissance. Sometimes one factor has to be weighed against another since few locations meet all (2) ________________.

(tactical) (2-20)

FRAME 2-21.

Convenient sites for development as bivouac areas and supply points may be important tactical requirements, as well as provision for artillery and armor units to leave the road to fire emergency missions. The latter would also enable traffic using the road to take cover in the event of an air attack. These tactical needs may require disregard of certain more favorable location ________________.

(secondary) (2-32)

FRAME 2-33.

The engineer study is NOT confined to single possibilities, but visualizes all alternate plans and the connecting of control features in various conceivable fashions. When certain control features must be ignored in selecting the final location, tertiary features are discarded before secondary and ______________ features give way to ______________.

(field) (location) (2-44)

FRAME 2-45.

Planning the location on a topographic map; preparing suitable plan, profile, and cross section drawings; and then staking out the planned location on the ground according to the drawings would be ______________ ______________.

(1) location (2) criteria (2-9)

FRAME 2-10.

Locating portions of the new road along and over **existing** roads, railroads, or trails is always a primary goal. The use of ________________ facilities shortens construction **time** and, in many cases, provides better roads than can be built from the ground up in the limited ________________ available during combat operations.

(criteria) (2-21)

FRAME 2-22.

In some cases, economy of engineer effort may dictate choosing a location with less desirable location ________________. Where the anticipated life usage falls within a predictable dry season, the criteria for ________________ may be disregarded.

(secondary) (primary) (2-33)

FRAME 2-34.

For each road location visualized, the engineer considers the various location criteria—clearing, cuts and fills, drainage, alinement, and so forth. Most of the work to this point can be done from maps or aerial photographs, which then indicate where detailed ________________ reconnaissance can be directed toward the most promising possibilities.

(paper) (location) (2-45)

FRAME 2-46.

Paper location permits adjustments aimed at securing better alinement and obtaining less severe grades, as well as simplifying drainage problems. It is easier to adjust the ________________ and ________________ on paper than to experiment on the ground.

(existing) (time) (2-10)

FRAME 2-11.

Topography (panel 2-2) is especially important to road location in mountainous terrain, where changing alinement and extensive grading (cut and fill) are usually necessary. Natural contour or stream lines are followed so far as practicable. When a road must cross a ridge between two valleys, ____________ is a criterion of particular importance.

(criteria) (drainage) (2-22)

FRAME 2-23.

Map reconnaissance and **ground** reconnaissance are two methods used for determining road location. Study of maps and aerial photographs can readily eliminate obviously undesirable routes and indicate one or more possible routes where ____________ reconnaissance might be made, minimizing wasted effort. In the final analysis, ____________ reconnaissance supplements ground reconnaissance, and one or both are employed with location reconnaissance.

(ground) (2-34)

FRAME 2-35.

Actual ground reconnaissance of the site (or sites) tentatively selected, concentrates on specific information requiring close scrutiny. For example, grades to be encountered are estimated, and timber cruising determines the clearing effort required by sampling 10 percent of the area. Tree diameters at breast height (DBH = 4.5 feet) are recorded along the clearance width of the proposed roadway. Timber cruising must be done by ______________ reconnaissance. Sampling 10 percent of the area and applying the result to the entire area is usually sufficient coverage. In small areas a 100 percent cruise may be made.

(alinement) (grades) (2-46)

FRAME 2-47.

If time permits, the paper location method of determining the final location of a road is preferred. The time spent in the preparation of a ______________ ______________ is repaid in better alinement and is directly reflected in both the decreased engineer effort needed for construction and the increased traffic capacity of the finished road.

(topography) (2-11)

FRAME 2-12.

Curves lower traffic capacit\ .nstitute hazards, particularly at the bottom of hills and on steep grades. S. rp curves at the end of long straight sections of road (poor **alinement**) are also dangerous. Road ________________ is a particularly important criterion for road location in rugged terrain.

Turn back to bottom of page 2-3.

Set 2. Hasty Location Methods

(ground) (map) (2-23)

FRAME 2-24.

In forward areas, the tactical situation usually requires the **hasty location** of a route over which the road can be most rapidly and easily constructed. Time is most always the controlling factor, therefore, ________________ ________________ is largely based on a study of maps and aerial photographs.

Turn back to top of page 2-4.

(ground) (2-35)

FRAME 2-36.

Soil gradations, stream conditions (width, depth, and velocity) at crossing sites, availability of construction materials, and approximate balance between cuts and fills are among other items recorded. Ground reconnaissance may uncover discrepancies in the ____________________ from which the site was originally selected. The effect of such errors on the selection must be considered.

Turn back to bottom of page 2-4.

(paper) (location) (2-47)

END OF FRAMES

PANELS AND SELF TEST FOLLOW

Panel 2-1. Example of a standard road reconnaissance report.

ROAD RECONNAISSANCE REPORT (FM 5-36)

DATE: 12 AUGUST 1973

TO: (Headquarters ordering reconnaissance) S-2 185th ECB

FROM: (Name, grade and unit of officer or NCO making reconnaissance) 1st Lt John J Smith 185th ECB

1. MAPS	a. COUNTRY	b. SCALE	c. SHEET NUMBER OF MAPS	2. DATE/TIME GROUP (Of signature)
	VIRGINIA, ALLANDALE	1:25000	US SHEET 556P 1 SW. AMS V834	101630R

SECTION I - GENERAL ROAD INFORMATION

3. ROAD GRID REFERENCE — FROM: 305024-294100 TO: 315060-292750

4. ROAD MARKING (Civilian or Military number of road): FAIRFAX 644

5. LENGTH OF ROAD (Miles or kilometers, specify): 6 7 MILES

6. WIDTH OF ROADWAY (Feet or meters, specify): 14-20 FEET

7. RECONNAISSANCE — DATE: 11 AUGUST 1960 TIME: 0800 - 1200

8. WEATHER DURING RECONNAISSANCE (Include last rainfall, if known): HOT, DRY, 95°F, LAST RAIN ABOUT 15 JUN 1960

SECTION II - DETAILED ROAD INFORMATION (When circumstances permit more detailed information will be shown in an overlay or on the mileage chart on the reverse side of this form. Standard symbols will be used.)

9. ALINEMENT (Check one ONLY)

	(1) FLAT GRADIENTS AND EASY CURVES
	(2) STEEP GRADIENTS (Excess of 7 in 100)
	(3) SHARP CURVES (Radius less than 100 ft (30m))
✓	(4) STEEP GRADIENTS AND SHARP CURVES

10. DRAINAGE (Check one ONLY)

✓	(1) ADEQUATE DITCHES, CROWN/CAMBER WITH ADEQUATE CULVERTS IN GOOD CONDITION
	(2) INADEQUATE DITCHES, CROWN/CAMBER OR CULVERTS, ITS CULVERTS OR DITCHES ARE BLOCKED OR OTHERWISE IN POOR CONDITION

11. FOUNDATION (Check one ONLY)

✓	(1) STABILIZED COMPACT MATERIAL OF GOOD QUALITY
	(2) UNSTABLE, LOOSE OR EASILY DISPLACED MATERIAL

12. SURFACE DESCRIPTION (Complete items 12a and b)

a. THE SURFACE IS (Check one ONLY)

✓	(1) FREE OF POTHOLES, BUMPS, OR RUTS LIKELY TO REDUCE CONVOY SPEED
	(2) BUMPY, RUTTED OR POTHOLED TO AN EXTENT LIKELY TO REDUCE CONVOY SPEED

b. TYPE OF SURFACE (Check one ONLY)

	(1) CONCRETE		(6) WATERBOUND MACADAM
✓	(2) BITUMINOUS (Specify type where known) SEE MILEAGE CHART		(7) GRAVEL
			(8) LIGHTLY METALLED
			(9) NATURAL OR STABILIZED SOIL, SAND CLAY, SHELL, CINDERS, DISINTEGRATED GRANITE, OR OTHER SELECTED MATERIAL
	(3) BRICK (Pave)		(10) OTHER (Describe)
	(4) STONE (Pave)		
	(5) CRUSHED ROCK OR CORAL		

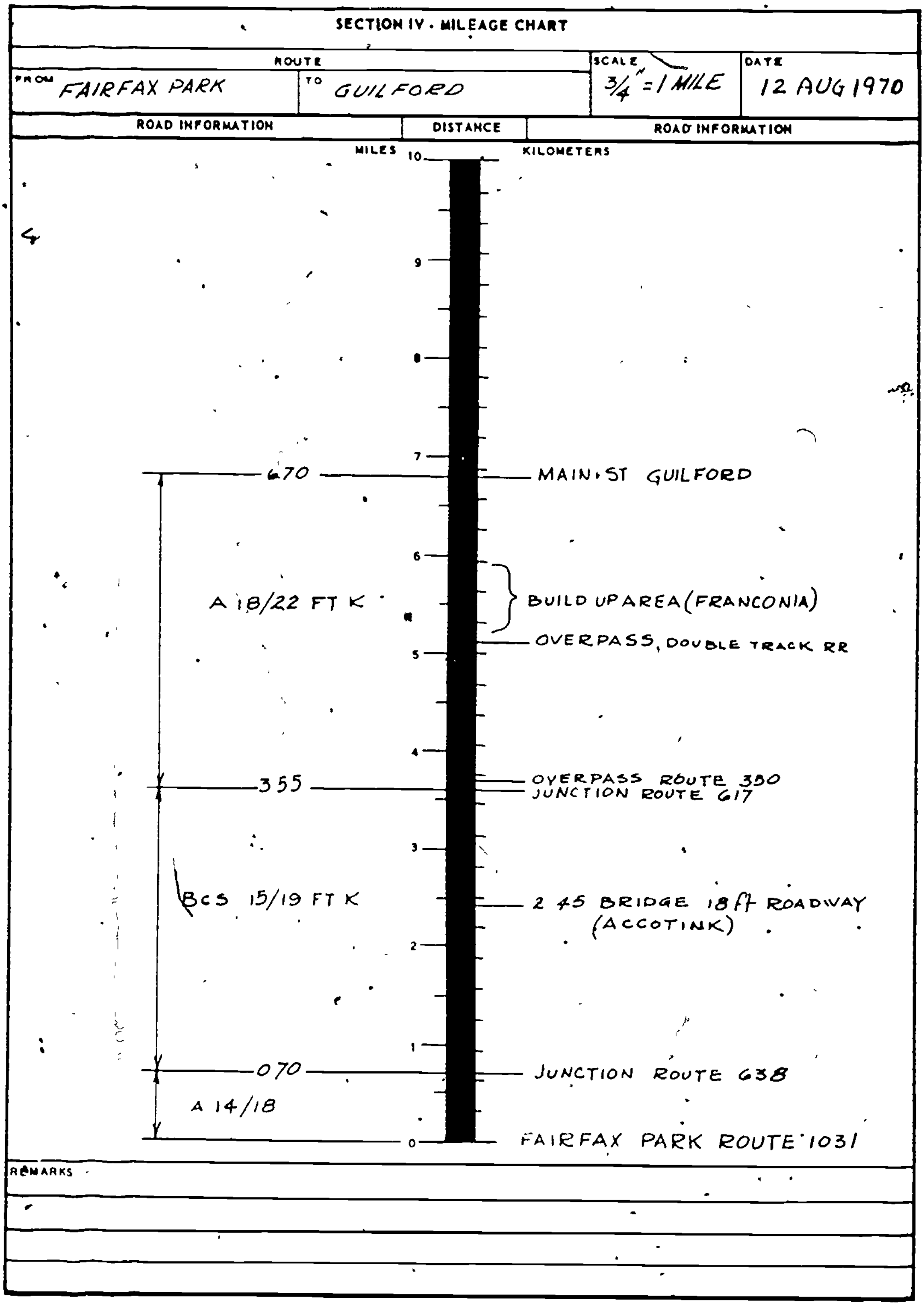
SECTION III - OBSTRUCTIONS (List in the columns below particulars of the following obstructions which affect the traffic capacity of a road. If information of any factor cannot be ascertained, insert "NOT KNOWN")

(a) Overhead obstructions, less than 14 feet or 4.25 meters, such as tunnels, bridges, overhead wires and overhanging buildings.
(b) Reductions in road widths which limit the traffic capacity, such as craters, narrow bridges, archways, and buildings.
(c) Excessive gradients (Above 7 in 100)
(d) Curves less than 100 feet (30 meters) in radius
(e) Fords

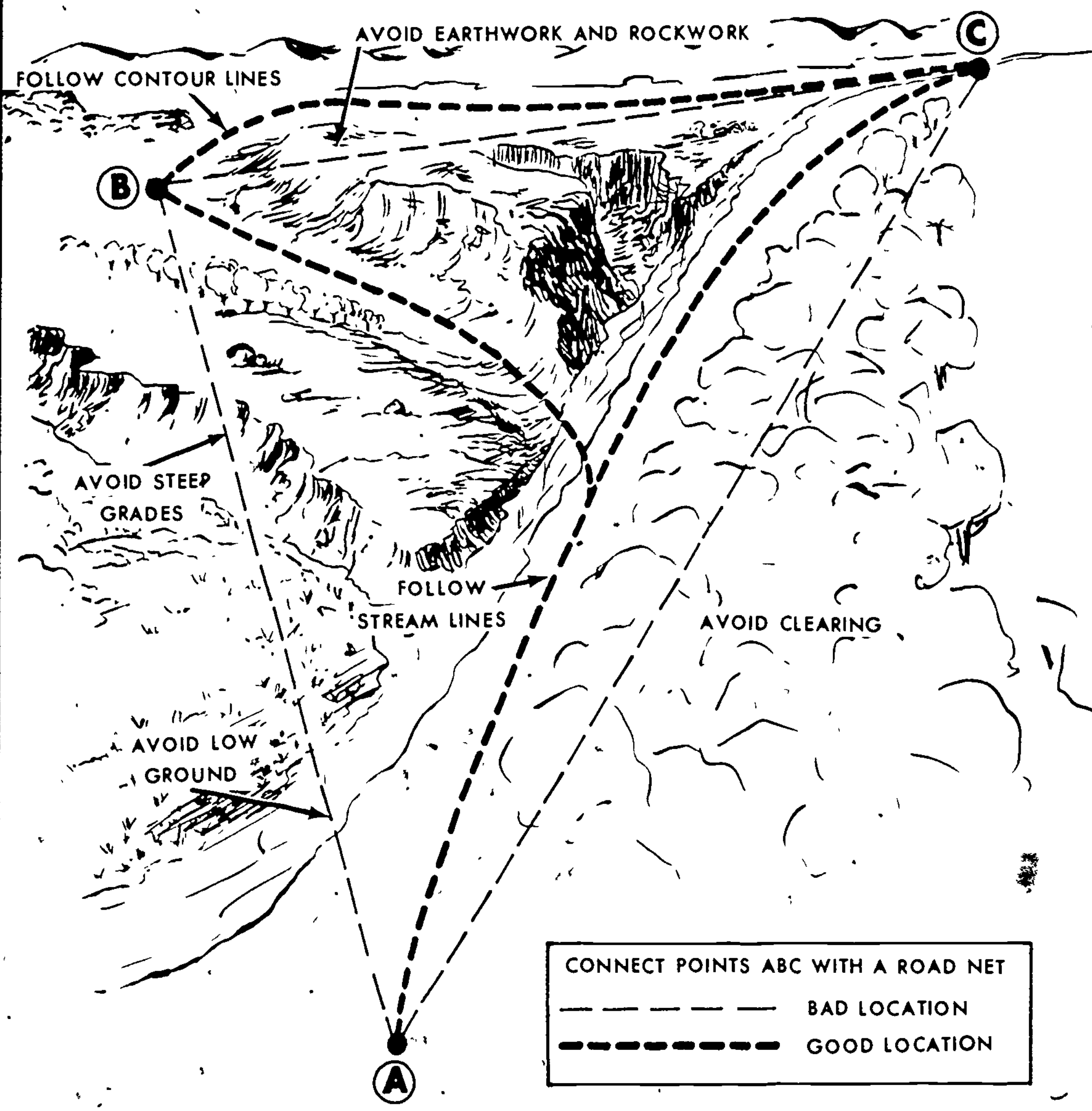
SERIAL NUMBER a	PARTICULARS b	GRID REFERENCE c	REMARKS d
1	STEEP GRADE - 8% UP HILL GOING -	305200 - 294250	
	EAST, 02 MILE LONG		
2	SERIES OF SHARP CURVES	305200-294250 to 305500-294300	
3	STEEP GRADE - 7% DOWN HILL	308000-293850	
	GOING EAST		

DA FORM 1 JUL 60 1248 PREVIOUS EDITION OF THIS FORM IS OBSOLETE

Panel 2-1. Continued.



Panel 2-2. Considerations of topography in road location.



Panel 2-3. Preliminary Survey.

1. The purpose of a preliminary survey is to furnish data needed for final location studies and decisions. It includes but is not limited to the following:

a. Establishment of a tentative centerline, staked out to the degree of accuracy required for the given situation.

b. Prominent terrain features (such as marshes, swamps, rock outcrops, or dense woods) which influence centerline location are plotted.

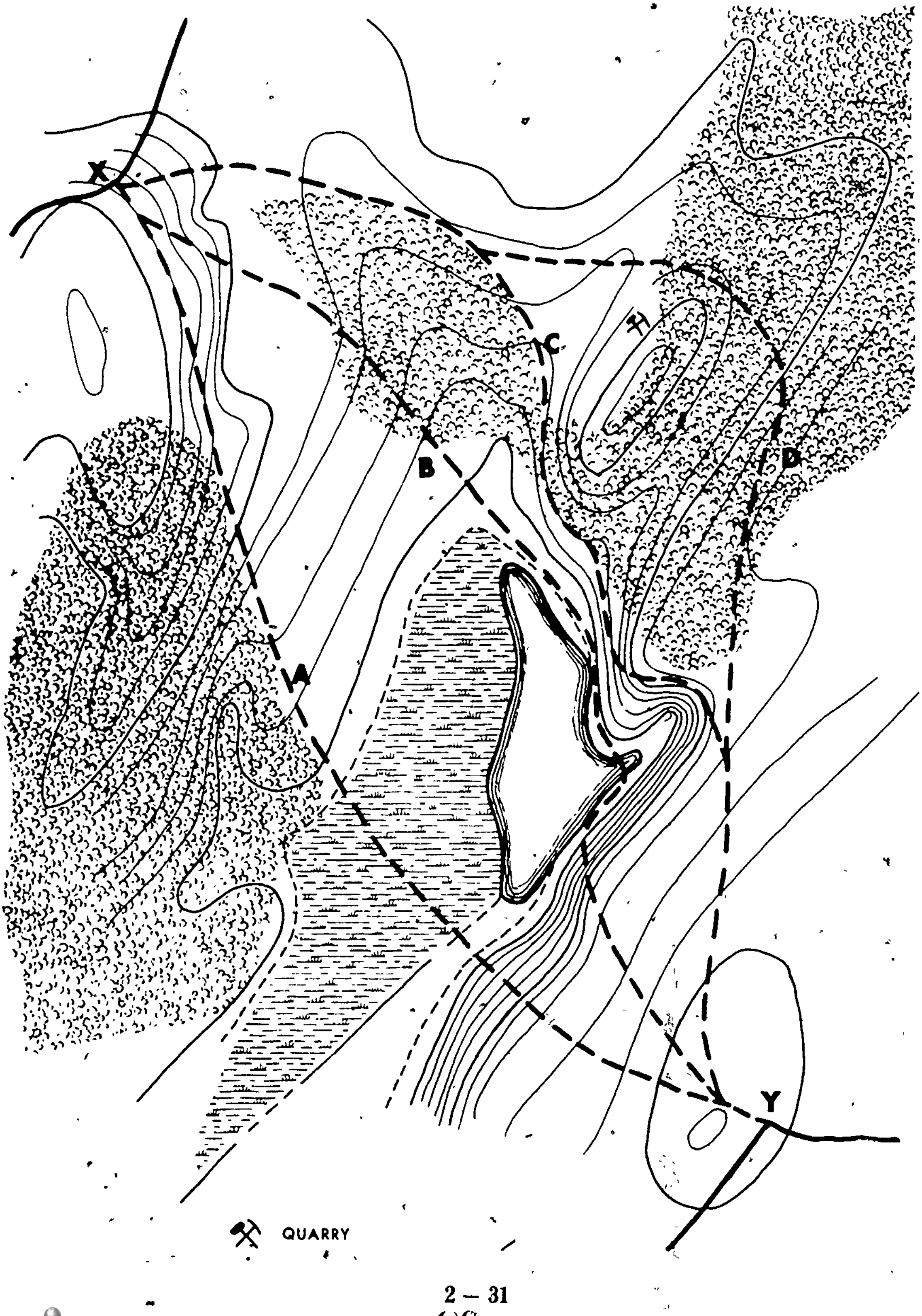
c. Elevations of key points which determine grades are plotted, and cross section elevations, sufficient in number for making earthwork estimates, are determined.

d. Field classification of the soils encountered.

2. Usually a map, showing the proposed centerline, the elevations of key points or contours, significant topography, and typical cross sections, is drawn to summarize the survey. Soil classification data is shown at typical locations on the map.

3. Sometimes the preliminary survey becomes an almost indistinguishable part of the final survey, but usually it is separate and distinct. The care with which the preliminary survey is accomplished, however, influences the extent of the final survey.

Panel 2-4. For use with exercise 25.



LESSON 2

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

1. Roads permit mobility essential to success in military operations. In selecting the route for a military road, what is the most important factor to consider? (frame 2-1 and 2-3)

2. The road reconnaissance obtains information about existing roads. What information does such a reconnaissance aim primarily at producing? (frame 2-4)

3. What items of information reported on DA Form 1248 properly belong in section II? (frame 2-6 and panel 2-1)

4. What are the reportable items of section III of DA Form 1248? (panel 2-1)

5. Periodic road reconnaissance provides information to keep the situation map up to date. Why do engineers need to coordinate this activity with units using the road? (frame 2-7)

____

____

____

6. Reconnaissance for a new road is made only after all possible existing roads have been eliminated from consideration. What type of reconnaissance is the first step for a new-road construction? (frame 2-8)

____

____

____

7. In locating a portion of a new road, support your choice of one of the following:

a. through a flat wooded area

b. on an abandoned railroad bed

c. along the side of a ridge

d. over a ridge between two valleys (frame 2-10)

____

____

____

8. The reconnaissance team must know about soils to locate the road on stable, well drained soils of high bearing quality. What type of soil makes a poor roadbed if present in appreciable amounts? (frame 2-13)

____

____

____

9. From an engineer viewpoint, explain which of the following sites would probably afford the poorest drainage.

a. parallel to the bank of a river

b. through a flat wooded area

c. an abandoned railroad bed

d. along the side of a ridge (frame 2-14)

10. In making a location reconnaissance it is essential that certain terrain characteristics be identified. Explain where a geologist's advise might be helpful. (frame 2-15).

11. Besides possible use as a natural road foundation, which considerations should be noted with regard to rock formations. (frame 2-16)

12. Why is the criterion of locating roads on the sunny side of slopes considered good practice? (frame 2-19)

13. Under what conditions should location criteria be subordinated in favor of tactical considerations? (frame 2-20)

14. Roads should be located so that vehicles can leave the road easily at frequent intervals. What is the purpose of this consideration? (frame 2-21)

15. What is the working relationship between map reconnaissance and ground reconnaissance? (frame 2-23)

16. The selection of a route for a road in a forward area (hasty location) is largely based on a study of map and aerial photographs. What usually supplements this study? (frame 2-25)

17. In deliberate location an engineer study is made to determine the best route for a new road. What considerations should be included in the engineer study? (frame 2-29)

18. Certain features along a proposed route control road location. For example, the terminal points where it starts and ends are primary control points. Describe other primary control points. (frame 2-30)

19. An indication of how features are classified is by importance. Give an example of third order control features. (frame 2-32 and panel 2-2)

20. The engineer visualizes alternate plans and sometimes must favor certain control features over others. When certain control features must be ignored in selecting the final location, some control features are discarded before others. What is the order of importance of control features with respect to final location? (frame 2-33)

21. When a road through a wooded area is considered, the clearing effort involved is usually estimated by timber cruising. What is the normal basis, in percent, for such an estimate? (frame 2-35)

22. Usually, a preliminary survey is made to furnish data for final location studies and decisions. In which way is the preliminary survey usually summarized? (frame 2-39 and panel 2-3)

23. In determining the final location of the route for the road, certain elements are weighed to find the most practical route. List those elements which must be evaluated. (frame 2-42)

24. The two methods of determining final location for a road are field location and paper location. If time permits, the paper location method is preferred. What is the principal advantage of the paper location method? (frame 2-47)

25. Panel 2-4 is a map indicating four possible routes for a new road connecting with existing roads at X and Y. Weighing the location criteria, which is the best route for final location of the road? Explain your choice. (frame 2-34 and panel 2-4)

LESSON 3

AIRFIELD RECONNAISSANCE AND SITE SELECTION

CREDIT HOURS ---- 2

TEXT ASSIGNMENT - Attached Memorandum.

LESSON OBJECTIVES

Upon completion of this lesson, you should, in the following subject areas, be able to:

1. **Types and elements of airfield reconnaissance** — Describe the difference between airfield and road reconnaissance, explain the classifications of airfield reconnaissance (area, specific and hasty or deliberate), and tell of the importance of proper briefing and timely reports.
2. **Steps in airfield reconnaissance** — Describe and explain the six steps involved in airfield reconnaissance (planning, briefing, preliminary study, air reconnaissance, ground reconnaissance, and reporting).
3. **Map reconnaissance and airfield siting template** — Discuss the need for preliminary studies and the procedures used in map reconnaissance, to evaluate potential sites and demonstrate the use of the siting template.
4. **Air reconnaissance** — Describe the air reconnaissance team, the job of the two members, and the procedures followed in an air reconnaissance.
5. **Ground reconnaissance** — Describe the sequence of a ground reconnaissance, jobs required, major items to verify, rough surveys, and the general procedures following rough surveys (runway location and staking of centerline).
6. **Reconnaissance reports** — Explain the procedure used in making reports and be able to fill out reports of air reconnaissances, of undeveloped airfield sites, and captured enemy airfields.
7. **Basic site requirements** — Describe the site selection process and the major requirements for airfield sites.
8. **Application of site selection requirements** — Apply the various considerations required in site selection (availability and adequacy of supply routes, approach zones, mental hazards, meteorological conditions, hydrological conditions, topography, soil characteristics, ground defense, and water) to analyze the selection of a given airfield site.

CONTENTS

Note: For the most part, except for area requirements (panel 1-7, lesson 1), reconnaissance for Army heliports is the same as that for airfields.

Set 1. Types and Elements of Airfield Reconnaissance.

FRAME 3-1.

Airfield reconnaissance differs from road location reconnaissance in two major considerations. First, an airfield project involves more manhours, more equipment hours, and more material than a road project. Secondly, air traffic, by its very nature, imposes more severe design criteria (see panel 1-4, lesson 1) than does vehicular traffic. In the interest of overall economy, ______________ reconnaissance requires an even greater degree of certainty that the site selected is the best site available than does ______________ location reconnaissance.

(air) (ground) (3-16)

FRAME 3-17.

The last step in airfield reconnaissance is that of (1) ______________. This is a continuing requirement and the importance of prompt, accurate, and complete reports cannot be overemphasized. Reconnaissance reports must be submitted to higher headquarters in accordance with the (2) ________-________-______________ schedule, established during the briefing step.

(passes) (questions) (3-32)

FRAME 3-33.

A previously discussed, airfield ground reconnaissance is preceded by two other types of reconnaissance. These are ______________ and ______________ reconnaissance. It was seen that these two types of reconnaissance discover or reveal those specific sites that merit ______________ reconnaissance.

(possibility or potential) (expansion) (3-48)

FRAME 3-49.

In general, the factors to be considered in site selection for an Army airfield are less demanding than those required for high-performance aircraft of the Air Force. Army aircraft are light in weight, have a very low tire pressure, and require very short ground take off and landing runs. Therefore, Army airfields can be constructed with shorter and narrower ______________. Less grading is necessary and steeper slopes may be used for Army airfields. (See panel 1-4, lesson 1.)

(airfield) (road) (3-1)

FRAME 3-2.

It was seen that roads had to be both feasible engineering-wise and adequate to accommodate the vehicular traffic to which they would be subjected. So must airfields be both feasible (1) ________________ ________________ and suitable for the air traffic which will use them. The difference is one of (2) ________________: air traffic imposes more severe (3) ________ ________ than does vehicular traffic.

Set 3. Map Reconnaissance and Airfield Siting Template.

(1) reporting (2) time-of-report (3-17)

FRAME 3-18.

As a part of its (1) ________________ ________________ (frame 3-12), the reconnaissance party conducts a map reconnaissance of the area or site involved. When the land or sea front is advancing rapidly (2) ________________ ________________ is also advantageous in selecting tentative airfield sites within enemy territory. These sites may be either undeveloped potential sites or operating enemy installations.

(map) (air) (ground) (3-33)

FRAME 3-34.

As in air reconnaissance (frame 3-29), enroute to the site to be investigated, the reconnaissance party should note and properly record ____________ routes. They would also note the location of ____________ materials and the position of potential water points.

(runways) (3-49)

FRAME 3-50.

For efficient operation, an Army airfield should be located near the unit it supports. Generally, the closer the unit air installation is to its unit command post, the more (1) ____________ the unit commander can use his aviation section to assist the (2) ____________ mission. Therefore, an Army airfield must be located (3) ____________ the unit it supports.

(1) engineering-wise (2) degree (3) design criteria (3-2)

FRAME 3-3.

Airfield reconnaissance may be classified as either area reconnaissance or specific reconnaissance. The first of these classes refers to a search conducted over a wide ________________ to find a suitable airfield site. The second refers to an investigation of a ________________ site, such as a captured enemy airfield, or a particular undeveloped but potential airfield location.

---

(1) preliminary study (2) map reconnaissance (3-18)

FRAME 3-19.

For best results, map reconnaissance must be conducted in an orderly fashion (panel 3-1). The first step in map reconnaissance is to select the ____________ available ________________ ________________ of the area in which the new airfield is to be located.

(access) (construction) (3-34)

FRAME 3-35.

When a definite site is involved, a more detailed observation of access routes should be made: For example, (1) ________________ capacities and (2) ________________ clearances must be checked; the capacity and suitability of railheads and sidings for use in connection with the construction must be investigated; and a detailed report of the (3) ____________ and (4) ____________ of construction materials must be prepared.

---

(1) efficiently (2) unit (3) near (3-50)

FRAME 3-51.

All existing facilities within the allowable area of site selection such as roads, abandoned airfields, parking areas, buildings, and so on, should be investigated. The use of long straight stretches of existing roads as a "center core" for an airstrip should be considered, especially where existing roads occupy the only favorable site within an area. An important basic requirement in airfield ______________ ______________ is the investigation of all ______________ facilities.

(area) (specific) (3-3)

FRAME 3-4.

With respect to comprehensiveness, the reconnaissance conducted in connection with an airfield location may be described as either **hasty** or **deliberate.** These terms have meanings here similar to their meanings with a road location reconnaissance (frames 2-24 and 2-29, lesson 2). A site selection based largely on a study of maps and aerial photographs would be called a ________________ location. The careful selection of a site based on a comprehensive and complete reconnaissance would be called ________________ location.

(best) (topographic) (map) (3-19)

FRAME 3-20.

Panel 3-1 pertains to frames 3-20 through 3-23. Existing airfields are marked with a ________________ -mile circle; high-tension electric lines are marked with a ________________ -mile wide strip. These areas should be ________________.

(1) bridge (2) overhead (3) quantity (4) quality (3-35)

FRAME 3-36.

The runway is obviously the most important part of the airfield. Therefore, when the site is reached, the most likely possibilities for a ______________ are first investigated. If the terrain is sufficiently open to permit good observation, these places may be quickly determined.

Set 8. Site Selection Criteria.

(site selection) (existing) (3-51)

FRAME 3-52.

Except for forward or support Army flight strips, airfields require concentrated materials and equipment; usually tactical situations demand construction within 72 hours. Therefore, one aim of site selection must be that of insuring that **adequate** supply channels (access routes) by land, water, or air are **available**. The more channels (1) ______________ to the site, the simpler the supply problem. The distance to the nearest railhead should be checked as should the (2) ______________ of the surrounding road net.

(hasty) (deliberate) (3-4)

FRAME 3-5.

For most efficient operation, the overall reconnaissance plan must be properly coordinated with all the various headquarters involved. The responsibility, therefore, for the reconnaissance effort cannot be that of the individual reconnaissance party alone, but must be through ______________ of the various ______________ interested.

---

(5) (2) (shaded) (3-20)

FRAME 3-21.

The next step is to identify and suitably (1) ______________ all other obstructions such as (2) ______________ towers. A ratio of (3) ______________ should be used for determining the diameters of circles marking such obstructions.

(runway) (3-36)

FRAME 3-37.

A rough survey of each selected runway possibility is carried out immediately. Lengths are paced or if possible are traversed by vehicle, critical slopes are measured with a clinometer, and directions are determined with a magnetic compass. The type of soil is noted, and hasty observations of a few samples are made. A ________________ ________________ of a runway possibility can be made in 15 minutes or so, if the terrain is reasonably clear and open.

(available) (adequacy) (3-52)

FRAME 3-53.

Freedom from interfering obstructions, particularly in the approach zones, is another criterion of site selection. An airfield site free of ________________ around the whole field is preferable, but an approach zone with no obstructions at each end of the flightstrip (panel 1-3, lesson 1) meets minimum requirements. Obstructions such as towers, pole lines, and stacks can often be removed; trees obstructing the approach zones and safety clearance zones must be removed.

(coordination) (headquarters) (3-5)

FRAME 3-6.

Reconnaissance missions must be based primarily on user requirements, which, in turn, are often governed by the tactical air support requirements of ground forces. The various headquarters must maintain close liaison with the Air Force and with each other. Each must know what reconnaissance the other is doing or has a need for. A lack of proper ________________ results in a wasteful duplication of effort on some areas or sites, while needed ________________ on other areas or sites goes undone or is inadequately covered.

---

(1) shade (2) radio (3) 50:1 (3-21)

FRAME 3-22.

After the (1) ________________ airfields and (2) ________________ have been appropriately marked, the study for the selection of potential new airfield sites is (3) ________________ to the (4) ________________ portions of the map.

(rough) (survey) (3-37)

FRAME 3-38.

In the event the terrain is not sufficiently open, the reconnaissance officer, accompanied by appropriate personnel, follows the perimeter of the area usable for runway and dispersal areas. He notes on a large scale map or sketch all obstacles which cannot be easily eliminated. A comparison of the reconnaissance notes discloses the possibilities for ________ ___ location and a ____________ ______________ is then made, as for open country.

(obstructions) (3-53)

FRAME 3-54.

Besides manmade and natural obstructions, there may be situations and layouts which might present a mental hazard to the pilot. An airfield on a plateau with steep sides falling away immediately beyond the overruns may have perfect approaches, for example, but pilots will always land well down the runways. A canel, ditch, or pole line at the end of a runway has the same effect. Such situations would be said to present a ________________ ________________. The result of these reactions is equivalent to a shortened runway.

(liaison or coordination) (reconnaissance) (3-6)

FRAME 3-7.

Airfield reconnaissance requires more engineering judgement than any other type of engineering reconnaissance. It is most unusual for one person to be proficient in all the items which a thorough reconnaissance must include. The party must be made up with due regard for the conditions it is likely to encounter. As with location reconnaissance for a new road (frame 2-15, lesson 2), a competent soils engineer or ______ ______ is a valuable member of the reconnaissance party.

---

(1) existing (2) obstructions (3) confined (4) unshaded (3-22)

FRAME 3-23.

The desirable features to look for in selecting potential new sites are: (1) ______ areas with good natural (2) ______, unobstructed air (3) ______, and proximity to (4) ______ routes.

(runway) (rough) (survey) (3-38)

FRAME 3-39.

The best runway location is selected by considering the rough survey investigations together with such other criteria as prevailing wind direction, approach zones, glide angles, and the clearing, grubbing and earthwork involved. The clearing and grubbing effort is estimated by ______ ______, the same as for roads (frame 2-18, lesson 2).

(mental) (hazard) (3-54)

FRAME 3-55.

Meteorlogical conditions must be considered in site selection. Wind, rainfall, fog, snow and frost are all meteorlogical conditions. The Air Force All Weather Service (AWS) maintains meteorlogical information for all populated areas of the world. Such data can also be found on both military and civilian maps, especially those prepared by marine and aeronautical agencies. The engineer must collect and evaluate all ______ information as a criterion of site selection.

(geologist) (3-7)

FRAME 3-8.

No reconnaissance party, however well qualified it may be, can satisfactorily perform a mission unless it is fully informed (briefed) as to just what that mission is. The party must know the type of airfield site for which it is reconnoitering, whether any site has been tentatively selected, or if some information has already been determined from preliminary study. Proper ______________ is essential to the conduct of airfield reconnaissance.

---

(1) flat (2) drainage (3) approaches (4) access (3-23).

FRAME 3-24.

A **siting template** is used to determine if the approach zones meet the **glide angle** requirements. This ______________ ______________ can be drawn on acetate to meet the glide angle specified, and the scale of the map employed. The template, when placed on the map, will readily show any land forms and natural or manmade obstacles which are in the ______________ ______________. Panel 3-2 is an example of such a siting template.

(timber) (cruising) (3-39)

FRAME 3-40.

Once the selection of a site is made, the centerline of runway is staked out and referenced to prominent features. This expedites the location of the selected (1) ________________ later by surveyors of the construction unit. Ground profiles are run at the (2) ________________ and at each shoulderline. Levels (elevations) are taken at each 500-foot interval, and at any breaks or slope changes. In flat country, this (3) ________________ may be increased to 1,000 feet.

(meteorological) (3-55)

FRAME 3-56.

If meteorlogical information is not available for a particular site, observations of the nearest point should be adjusted to changes that will result locally from the topography or other influencing factors. Interviews with local inhabitants may help to confirm ________________ data and, in some cases, may be the only source of such information. If practical, sites near prominent topographic features should be flight-tested by an experienced pilot to disclose the existence and effect of any local air eddies and currents that may be present.

(briefing) (3-8)

FRAME 3-9.

The submission of timely reports is an essential element of good airfield reconnaissance. Higher headquarters must receive the reconnaissance (1) ______ in time to permit necessary planning and preparation before engineer units are committed. A time-of-report schedule must be prescribed and rigidly adhered to. Reconnaissance is of no value if the information is (2) ______________ in reaching headquarters.

---

(1) siting template (2) glide angle (3-24)

FRAME 3-25.

Referring to panel 3-2, any hill, within the approach zone at a distance of 10,000 feet from the end of the overrun and having an elevation of more than ______________ feet would be inside a 50 to 1 glide angle. Such a runway would be ______________ if the required glide angle is 50 to 1.

(1) runway (2) centerline (3) interval (3-40)

FRAME 3-41.

As stated previously, timely reports are an essential element of airfield reconnaissance. Use of standard formats is desirable and facilitates comparative evaluation of two or more sites, particularly when the sites have been reconnoitered by different parties. Using the same ________________ for all sites, results in a better ________________ between sites.

(meteorological) (3-56)

FRAME 3-57.

The hydrological considerations to be investigated include the height of the ground-water table and its seasonal variations, the flood characteristics of streams bordering the site, and tidal variations at coastal stations. This is most important; drastic changes may take place between wet and dry seasons. Unless care is taken, evaluation of ____________ considerations made during the ____________ season may be misleading.

Set 2. Steps in Airfield Reconnaissance.

(1) report (2) late (3-9)

FRAME 3-10.

There are six steps in airfield reconnaissance: planning, briefing, preliminary study, air reconnaissance, ground reconnaissance, and reporting. The formulation of a reconnaissance mission is concerned with the (1) ________________ step. The planning step involves (2) ________________ of the reconnaissance effort by appropriate headquarters, prediction of user requirements, and assignment of a definite reconnaissance (3) ________________.

Set 4. Air Reconnaissance.

200 (unsuitable) (3-25)

FRAME 3-26.

An air reconnaissance team usually consists of only two members — the pilot and the engineer observer. The obvious advantages of having the officer in charge of the ground reconnaissance party serve as ________________ observer should be realized. Likewise, the ________________ is very much a part of the air reconnaissance team, NOT merely a chauffeur.

(format) (comparison) (3-41)

FRAME 3-42.

Reconnaissance reports can be submitted in writing or by radio, but a (1) ______________ report usually should be followed up with a detailed written report. Referring to panel 3-4, the statement "the overall estimate of the site is excellent" would be transmitted as (2) ______________.

(hydrological) (dry) (3-57)

FRAME 3-58.

Topography is probably the most important criterion in site selection. A site with favorable ______________ is one located on high ground, with sufficient slope for cross and longitudinal drainage, and a reasonably smooth surface requiring little earthmoving. Uphill takeoffs and downhill landings require longer runways.

(1) planning (2) coordination (3) mission (3-10)

FRAME 3-11.

Telling the reconnaissance party exactly what area or site is to be reconnoited, what is already known about the area or site, and what specific information the party is expected to obtain is accomplished during the ________________ step. Pertinent details concerning the times and methods of reporting are also included in the ________________ step.

(engineer) (pilot) (3-26)

FRAME 3-27.

The pilot considers such flying problems as approaches, mental hazards, and physical obstructions, as related to combat type planes which may use the proposed airfield. The value of a pilot who is familiar with ________________ requirements, affect of mental ________________ on landing and take off, and limitations imposed by physical ________________ is apparent.

(1) radio (2) BRAVO EXCELLENT (3-42)

FRAME 3-43.

Panel 3-5 is an example of a written air reconnaissance report. The given example indicates that the site is classified as ______________ and the flying approaches are ______________.

(topography) (3-58)

FRAME 3-59.

Soil characteristics and quality of subgrade are also important factors in airfield site selection. Whether stabilization or surfacing is required depends on the characteristics of the soil. Also the character of the soil controls the thickness of the base course. Whether the surfacing or pavement can be placed directly on the subgrade or whether a ______________ ______________ is required depends on the ______________ of the soil.

(briefing) (briefing) (3-11)

FRAME 3-12.

The preliminary study represents the initial work by the reconnaissance (1) ______________. The party studies the information obtained during the (2) ______________, conducts a map reconnaissance of the area or site involved, and studies air photos. Also, during the (3) ______________ study, soil boundaries are delineated, other preliminary information is assembled, and the actual (4) ______________ is planned and prepared for.

(approach) (hazards) (obstructions) (3-27)

FRAME 3-28.

The engineer observer is not as familiar with flight requirements and characteristics of aircraft. He is familiar with the **construction** problems which may be encountered, and assesses the potential site in terms of ______________ effort. He receives the pilot's suggestion concerning the flying characteristics, and modifies his own estimate in accordance with such recommendations.

(good) (average) (3-43)

FRAME 3-44.

Panel 3-6 is an example of a report on an undeveloped airfield site. This report indicates that the proposed site has (1) ______________ drainage and does not require (2) ______________ clearing. Suitable **sketches** (panel 3-7) should be attached to all written reconnaissance reports. Such (3) ______________ enable the reader to visualize the site more fully.

(base coarse) (characteristics) (3-59)

FRAME 3-60.

Ground defense of the airfield is another criterion. Terrain favorable for defense provides observation, fields of fire (both ground and air), concealment, obstacles, and routes of communication. The practicality of (1) ______________ ______________ against both (2) ______________ and (3) ______________ attack must be considered.

(1) party (2) briefing (3) preliminary (4) reconnaissance (3-12)

FRAME 3-13.

Reconnoitering the area or site by observations made from the air (flying over) facilitates the reconnaissance mission. A general study of the topography, drainage, construction problems, camouflage possibilities, and location of access routes can all be visualized from ______________ made by ______________ ______________.

(construction) (3-28)

FRAME 3-29.

Panel 3-3 pertains to frames 3-29 through 32. In planning airfield construction projects, access routes and sources of construction materials are important considerations. En route to the site or a general area, the engineer observer would note (1) ______________ pits or (2) ______________ sites and rail or road (3) ______________ routes. He would also note any obvious (4) ______________ on maps that have been studied.

(1) good natural (2) extensive (3) sketches (3-44)

FRAME 3-45.

Panel 3-8 shows that reconnaissance of a captured enemy airfield requires more detailed information than that required for an undeveloped area. For example, the report indicates that the field has a ________________ foot, ________________ surfaced main runway, but that the generator system required to furnish electric utilities is __________ __________ __________.

---

(1) ground defense (2) ground (3) air (3-60)

FRAME 3-61.

As in road construction (frame 2-17, lesson 2), an adequate supply of water is essential for airfield construction work. Construction requirements for water will be a major consideration when the moisture content of the soil is far below the optimum for compaction. Water for personnel must also be provided, both during construction and subsequent airfield operations. The ________________ and ________________ and accessibility of ________________ sources must always be determined.

(observations) (air) (reconnaissance) (3-13)

FRAME 3-14.

Usually, specific ground reconnaissance procedure is planned by selecting from (1) ________________, what areas need investigating and what questions need answering. Air reconnaissance will give valuable negative information by eliminating unsuitable sites, but cannot be relied upon for (2) ________________ information. (3) ________________ reconnaissance is required for this.

---

(1) borrow (2) quarry (3) access (4) errors (3-29)

FRAME 3-30.

The engineer observer studies the topography, drainage patterns, general soil conditions, and camouflage possibilities. He estimates these factors from the point of view of the essential ________________________________. The pilot estimates the ________________ characteristics of the site.

Set 7. Basic Site Requirements.

(4700) (concrete) (damaged) (beyond) (repair) (3-45)

FRAME 3-46.

As in road location, the selection of airfield sites is usually a compromise between engineering, operational, and tactical requirements. In order to meet time limitations dictated by the ______________ requirement, ______________ considerations sometimes outweigh ______________ considerations, particularly in such matters as orienting the runway with respect to the prevailing wind direction.

(quantity) (quality) (water) (3-61)

FRAME 3-62.

Also, as in road construction (frame 2-18, lesson 2), the effects of clearing on camouflage may be significant. Ground cover in areas adjacent to the flightstrip is desirable, since it affords natural concealment for parked aircraft, fuel and ammunition storage, and operational facilities. To aid in ______________, standing trees and brush outside the flightstrip are not removed or touched unless necessary.

(1) air (2) positive (3) ground (3-14)

FRAME 3-15.

The next step in airfield reconnaissance is the performance of ground reconnaissance. While air reconnaissance can effectively minimize the amount of ground reconnaissance which is necessary, it cannot replace this important step. It is on the ____________________, that most questions are answered, or that most questions from the ____________________ are verified.

(engineer) (criteria) (flying) (3-30)

FRAME 3-31.

In reconnoitering a tentatively selected site, at least (1) ____________________ passes are made at (2) ____________________ feet; the final circuit is flown at (3) ____________________ feet. The length of the proposed runway is determined by multiplying the air speed by the average time of two passes flown in opposite directions about (4) ____________________ yards on each side of the centerline.

(tactical) (engineering) (operational) (3-46)

FRAME 3-47.

The size of the site must afford suitable area for the required flightstrip and all allied features and facilities. Therefore the overall ____________ of the airfield is most important.

(camouflage) (3-62)

END OF FRAMES

PANELS AND SELF TEST FOLLOW

(ground) (air) (3-15)

FRAME 3-16.

Often, ground and air reconnaissance are not as distinct as they would seem to be from this discussion. A continuing ________________ reconnaissance may be interspersed with ________________ reconnaissance.

Turn back to bottom of page 3-3.

---

(1) three (2) 300 (3) 200 (4) 50 (3-31)

FRAME 3-32.

In departing from the site, dispersal areas are reviewed, and access roads as well as sources of construction material are again checked. Additional ________ over the site are made if any further ________________ arise as a result of this check.

Turn back to top of page 3-4.

(size) (3-47)

FRAME 3-48.

Also, consideration should be given to the possibility of expanding the proposed site. This is rarely a deciding factor in the choice of a tactical airfield location, but it is important and may sometimes govern any decision between otherwise acceptable locations. If a site possesses any ________________ for ________________ of the runway, it should be noticed and reported.

Turn back to bottom of page 3-4.

Panel 3-1 Procedure for Map Reconnaissance

1. Select the best available topographic map of the area in which the new airfield is to be located.

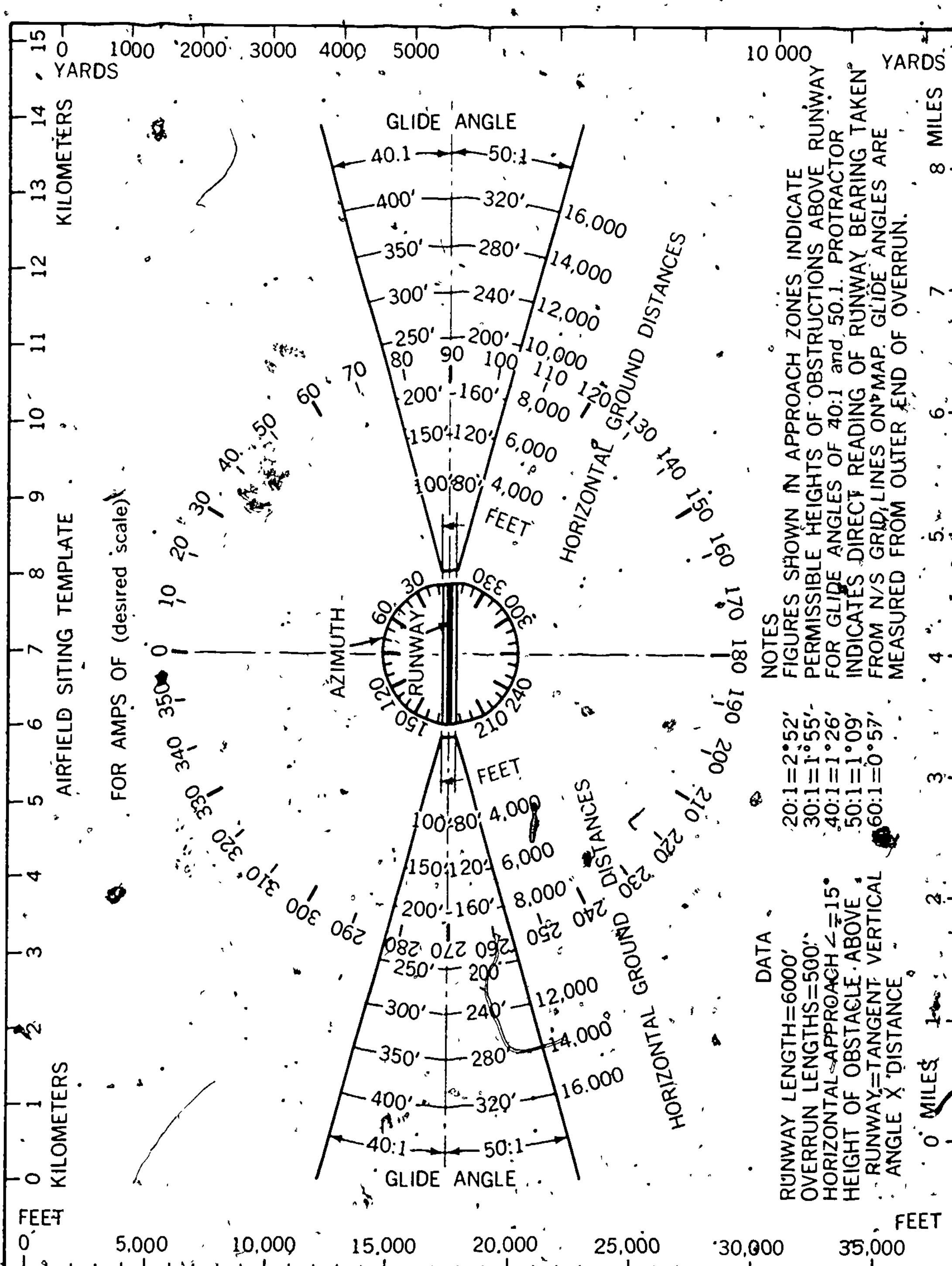
2. Draw a 5-mile circle ($2\frac{1}{2}$-mile radius) around existing airfields; shade these circles.

3. Note all high-tension electric transmission lines: shade a 2-mile wide strip centered on such lines.

4. Locate and suitably shade all other obstructions such as radio towers, high water tanks, and so on. The diameters of circles marking such obstructions should be based on the specified glide angle.

5. Now confine the study for potential new airfield sites to the unshaded portions of the map. Look for sites of sufficient area, preferably flat with good natural drainage; unobstructed air approaches; and accessibility to route of communication.

Pannel 3-2. Sample Airfield Siting Template



Panel 3-3. Air Reconnaissance

1. EQUIPMENT

Two place, fixed wing aircraft, such as the 0-1, or two-place helicopters, such as the OH-13 or OH-23, are suitable for the majority of air reconnaissance missions. Reconnaissance of enemy occupied territory is best accomplished with combat type planes.

2. PROCEDURE

The general procedure for an air reconnaissance is as follows:

a. En route to a particular site or a general area, the engineer observer notes such items as open borrow pits, large stockpiles of construction materials or quarry sites, rail and road accesses to the site or area, and obvious errors on maps that have been studied.

b. Within a designated area, specific tentative sites must be selected. The engineer observer studies topography, drainage patterns, general soil conditions, earthmoving problems, routes of communication, and camouflage possibilities. He bears in mind the engineer criteria for selecting an airfield site (set 8) and selects potential sites for closer investigation.

c. Upon approaching a designated site for specific reconnaissance, or upon approaching a tentatively selected site during an area reconnaissance, the normal altitude for the first circuit is about 300 ft. Not more than orientation can be accomplished in this circuit, but sometimes a site selected tentatively during an area search can be eliminated during this pass or the next few passes.

d. Similar second and third passes flown at the same height. During these circuits, obstructions, main slopes, and similar general features are noted. The pilot begins to formulate his estimate of the flying (flight) characteristics of the site. Pinpoints for the ends of the runways are made on the map during these circuits, but additional trips should be flown across the site if necessary for such selection.

e. After the runway has been tentatively selected, an initial low pass over the proposed runway is made at about 50 yards to one side of the proposed centerline. A second low pass in the opposite direction is then flown on the other side of the centerline. Both of these flights should be made at a constant speed so that the runway length can be estimated by multiplying air speed (feet min or feet-sec) by average flight time (min or sec). A stop watch should be used to determine the time.

> CAUTION: The length usually will be considerably over-estimated when flying at low air speeds if a strong wind is blowing along the centerline. This effect can be minimized if distances obtained by two passes in opposite directions along the proposed centerline are averaged (if wind is constant).

f. A final circuit is then flown at about 200 feet. During this trip, the ends and centerline are given a final check, and the pilot completes his appraisal of the field's flying suitability.

g. In departing from the area, dispersal areas are reviewed, and access roads are again checked. Additional passes over the site are made if any further questions arise as a result of this last check.

h. An area reconnaissance then proceeds by similar inspection of other possible sites. Complete notes must be kept to minimize the necessity for reviewing sites already checked, but a reinvestigation of the finally selected site and any alternate sites may sometimes be necessary or desirable.

Panel 3-4. Code for Transmitting Airfield Reconnaissance Reports by Radio

Signal	Meaning of Signal	Adjectives to Follow Signal
ALFA	"The coordinates of the center of the runway are . . ."	(Follow with coordinates.)
BRAVO	"Overall estimate of the site is . . ."	"Excellent", "fair", "poor", "Possible", or
CHARLIE	"Density of necessary clearing and grubbing is . . ."	"Heavy", "medium", or "light"
DELTA	"Amount of earthmoving necessary is . . ."	"Great", "moderate", or "light"
ECHO	"Predominant type cf soil is . . ."	"Sandy gravel", "sand", "sandy silt", "sandy clay", "silt", "clay", "Peat, muck, or swampland", or "rock outcrops".
FOXTROT	"Moisture conditions of the surface soil are . . .".	"Wet", meaning flooded or that ground water is close to the surface; "damp", meaning soil is wet enough that equipment operation might be difficult; or "dry", meaning that, as far as moisture is concerned, equipment can operate easily.
GOLF	"Glide angle is . . ."	"Unquestionable", "close", or "impossible"

Panel 3-5. Air Reconnaissance Report

AIR RECONNAISSANCE REPORT

DATE 29 SEPT 61 NO. 4

1. To CO 327 ENGR BN. 3. Map Sheet JOHANNASVILLE QUADRANGLE

2. From CO. C 4. 10 MILES NORTH OF JOHANNASVILLE
(Nearest main road center)

5. (a) Coordinates of EAST end of runway N3 765, E 1 900

(b) Length (feet) 5000 FT. BUT MIGHT BE EXTENDED 2000 FT (SEE ITEM 12)

6. Classification of Site (overall):

Excellent___ Good √ Fair___ Poor___ Reject*___

7. Natural Surface Drainage:

Excellent___ Good √ Fair___ Poor___

8. Flying Approaches:

Excellent___ Average √ Poor___

9. Clearing:

Light √ Moderate___ Excessive___

10. Aircraft Dispersal:

Unlimited √ Adequate___ Inadequate___

11. Access Roads:

Good___ Adequate √ Inadequate___

12. Remarks: EXTENSION MENTIONED IN 5(b) ABOVE MUST BE CHECKED AS THERE MAY BE A SWAMP AREA IN THAT SUGGESTED EXTENSION. CANNOT BE CERTAIN FROM AIR OBSERVATION.

H Bobinder
(Signature)

1400
(Time)

*If "Reject" classification is indicated, reason(s) for same will be given under remarks.

Panel 3-6. Reconnaissance Report on Undeveloped Airfield Site

RECONNAISSANCE REPORT
UNDEVELOPED AIRFIELD SITE

TO Commanding Officer 527 ENGR BN

FROM. CO C CP DATE 29 SEPT 71

Note --The reconnaissance party must be furnished with the following information
a Location of airfield -- general or specific
b Type of aircraft that will occupy the airfield
c Number of groups expected to occupy the airfield

DESIGNATION Name CHELTENHAM AIRFIELD Number

LOCATION:

a Map reference BAYS VILLAGE OF MARYLAND / MD DEPT OF PUBLIC IMPROVEMENTS SCALE 1:600 ... Elevation ... 225 FT
(NAME and SCALE)

c Latitude & longitude 38° 44' N LAT 76° 40' WEST LONG Map coordinates N 528 ... E 344 59

d Nearby towns CHELTENHAM (POP 100) 1.5 MI DUE EAST FROM SITE
Size distance and direction from site

ROADS US 301 AT CHELTENHAM EXCELLENT BITUM GOOD GRAVEL ROAD FROM SITE WEST TO LOCAL ROAD NET
(Type, condition, bridges, fords, etc)

RAILROADS PENNSYLVANIA RR SIDING AT TOWN 2 MILES EAST OF SITE
Gage condition distance from site loading capacity

GENERAL DESCRIPTION OF LANDING AREA AND SURROUNDING COUNTRY SITE NOW DETENTION HOME FOR DELINQUENT BOYS ... AGRICULTURAL AREA US NAVAL RADIO STATION

GLIDE ANGLES NEARLY UNLIMITED IN MOST DIRECTIONS SEE ITEM 7
Direction, slope distance

FLIGHT OBSTRUCTIONS AND MENTAL HAZARDS ANTENNA FARM AT NRS 5.5 MI N OF SITE, ELEVATED WATER TOWER, EAST OF SITE AT BLM
(Ravines, cliffs, mountains, timber, steeples, country ... streets, power lines etc)

METEOROLOGICAL CONDITIONS WESTERLY WINDS - LITTLE FOG - NORMAL MD PRECIPITATION AND RAIN
Prevailing winds, storms, frost, precipitation, temperature, etc

HYDROLOGICAL CONDITIONS STREAMS ON EACH SIDE OF SITE RUN TO PISCATAWAY RIVER
(Streams, ground water, flood conditions, tidal variations)

DRAINAGE GOOD NATURAL DRAINAGE
(Flat, sloping, direction, number of culverts ... etc)

SOIL TYPES AND GEOLOGICAL DATA CLAY AND GRAVEL
(Sand, gravel, clay, etc, or combination ... rock outcrops ... etc)

CLEARING NO EXTENSIVE CLEANING, FEW ISOLATED TREES - 4 ABANDONED FRAME BUILDINGS ... HAVE TO BE REMOVED
Area, size and density of timber ... etc

PROPOSED LAYOUT NE-SW RUNWAY, USE EXISTING BLDGS 2500 FT RUNWAYS SUITABLE FOR F-5 ... AND F-82 ...
Location and direction of runway and dispersal system, attach sketch

RECOMMENDED SURFACING PSP OR SIMILAR PORTABLE SURFACING
PSP, SMT, PRS, mechanical stabilization, etc

CAMOUFLAGE LITTLE NATURAL CONCEALMENT AFFORDED ADEQUATE DISPERSAL POSSIBLE
(Cover, concealment, dispersion, deception)

BIVOUAC AREAS USE EXISTING DORMITORIES - WILL ACCOMMODATE 450 MEN
Location, size, cover, previously occupied

WATER SUPPLY PUMPS, ELEVATED TANK AND DISTRIBUTION SYSTEM IN OPERATION SMALL STREAMS AFFORD ADEQ. FIRE PROTECTION
(Source, location, quantity, quality)

EXISTING FACILITIES SEWAGE TREATMENT NEEDS REPAIR POWER PLANT OPERABLE, ELECTRIC WIRING SUITABLE, GENERATORS MUST BE INSTALLED
Buildings, storage, power, water, sewerage

MATERIALS AVAILABLE GRAVEL PIT 4 MI S MUCH TIMBER NEAR PIT CINDER PILE AT POWER PLANT, WAREHOUSE SPACE AVAILABLE
(Equipment, borrow pits, gravel banks, quarries ... timber)

WORK ESTIMATE -- QUANTITIES

a. Clearing NEGLIGIBLE
(Acres, size of timber, density)

b Drainage OPEN DITCHES AROUND PERIMETER OF RUNWAY AND TO STREAMS
(Linear feet of open ditching, number of culverts, amount of pipe and approximate diameter)

c Earth moving ABOUT 4000 CUBIC YDS NO BORROW SPOIL OR LONG HAUL
(Estimate for R W, T W, H S)

d Surfacing LAY ABOUT 120,000 SQ FT M-8
Quantity for R W, T W, H S, recommended type

e. Roads -- access and service ACCESS EXIST SOME SERVICE NEED SUPPLEMENTING
Miles, condition

f Buildings PRESENT BLDGS SUITABLE BUILD CONTROL TOWER
(Number and size, suitability for operations, quarters etc)

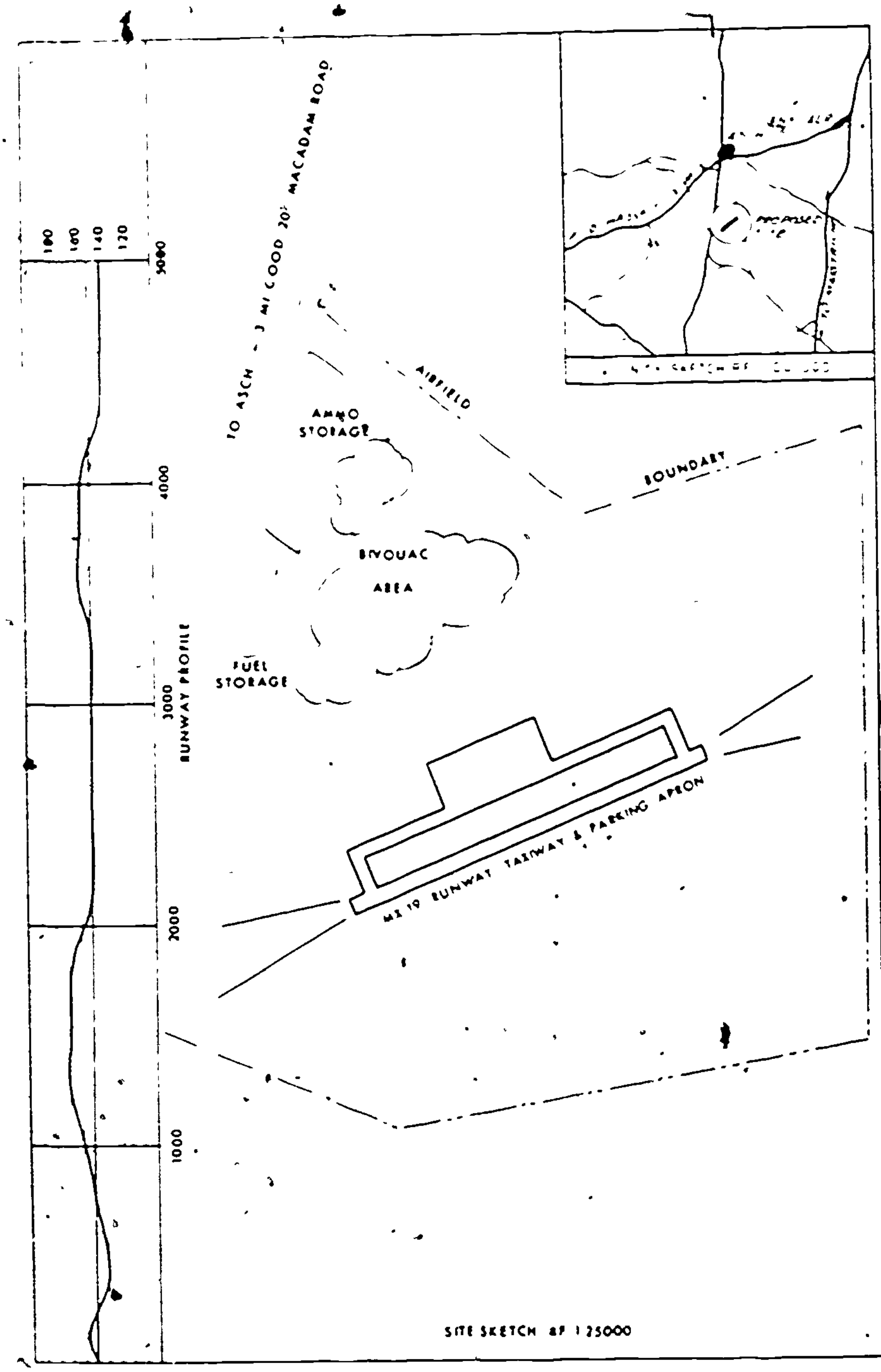
TIME ESTIMATED FOR COMPLETION 4 CO-DAYS
(Bn-days or Co-days)

ADDITIONAL INFORMATION
1. NO TOPOGRAPHIC MAPS AVAILABLE FROM MD DEPT OF PUBLIC IMPROVEMENTS. CIVILIAN PERSONNEL IN AREA COULD BE USED FOR CONSTRUCTION. NATIVES APPEAR FRIENDLY. PART OF PROPOSED RUNWAY UNDER CONSTRUCTION DAIRY HERD AND MILK PROCESSING PLANT AT SCHOOL.

ANNEXES SEE ATTACHED MAP AND OVERLAY
(Maps, photographs, sketches, estimates, samples)

SIGNATURE 2LT M B James
(In charge of reconnaissance party)

Panel 3-7. Sketch Attached as Annex to Airfield Reconnaissance Report



Example of sketch form to be attached as annex to written reconnaissance report on an airfield site.

Panel 3-8. Reconnaissance Report on Captured Enemy Airfield

RECONNAISSANCE REPORT
CAPTURED ENEMY AIRFIELD

TO [illegible]

FROM [illegible] DATE 29 SEPT 71

1. DESIGNATION Name BONGO BONGO AIRFIELD Number 1

2. LOCATION
 a. Map reference PRINCIPALITY OF BONGO MAP 3 SCALE [illegible] Elevation 750 FT MSL
 Lat. and longitude [illegible] Map coordinates N 5 [illegible] E 3 235
 b. Nearest town BONGO BONGO [illegible] MILES NE OF SITE POPULATION ABOUT 4000

3. RUNWAYS

	Length	Width	Direction	Surface	Possible extension
(1) E-W RUNWAY	7000	150	35°-215°	CONCRETE	2300 FT
(2) N-S RUNWAY	2000	80	350°-170°	CONCRETE	NONE
(3) NONE					

4. HARDSTANDS: Number 2 Type [illegible] OF MAIN RUNWAY CONCRETE [illegible] OF AUX RUNWAY CONCRETE

5. OTHER AIRFIELD FACILITIES
 a. [illegible] AUX RUNWAY FAIR BUT NEEDS MINOR REPAIRS. MAIN RUNWAY EXCELLENT BUT EAST MOST [illegible] FT NEEDS REBUILDING
 Taxiways GOOD
 Parking [illegible] ABOUT HALF OF EACH USEABLE [illegible] IN EXCELLENT SHAPE FOR LIGHT CRAFT
 c. Approach [illegible] From EAST [illegible] FROM NORTH [illegible]
 [illegible]
 d. Gas [illegible] EMBANKMENT-PROTECTED DRUM STORAGE AREAS. NO TANKS OR PIPE LINE
 e. Bomb and ammunition dumps SIMILAR TO ITEM E
 f. [illegible] NONE IN SERVICEABLE OR REPAIRABLE CONDITION
 g. [illegible] ONE 3 STORY BRICK BLDG 50 FT X 50 FT BURNED BUT CAN BE EASILY RESTORED
 Shop space ONE OPEN-TYPE ROOFED AREA 300 FT X 20 FT WITH WOOD BLOCK FLOOR [illegible] FORMERLY USED AS SHOP AREA NO EQUIP REMAINING
 Storage space [illegible] 3 FRAME BLDG EA [illegible]
 h. Drainage [illegible] STORM SEWER SYSTEM SLIGHTLY DAMAGED [illegible] NEEDS MINOR REPAIR OUTFALL OF SYSTEM AT GOBOLOGASS RIVER BORDER ON SOUTH SIDE OF INSTALLATION
 i. Utilities
 Water supply RIVER IS SOURCE NO PURIFICATION SYSTEM - PUMPS AND PIPES ADEQUATE FOR FIRE PROTECTION
 Sewerage system OUTDOOR LATRINE SYSTEM NEEDS CLEANING REPAIR OR REBUILDING
 Electric [illegible] ADEQUATE - GENERATOR SYSTEM DAMAGED BEYOND REPAIR
 Heating systems type NONE NEEDED
 j. Other [illegible] CONTROL TOWER ADEQUATE - [illegible] TARGET RIFLE RANGE 20 MILES N
 k. Railroads SINGLE TRACK [illegible] BONGO BONGO [illegible] DOUBLE TRACK [illegible] BONGO BONGO [illegible] PORT

6. PERMANENT TROOP HOUSING ON OR ADJACENT TO AIRFIELD
 Capacity [illegible] 2 [illegible] MAN BARRACKS [illegible] 50 MAN BARRACKS

7. BIVOUAC AREAS PUBLIC PARK AREA ADJOINING AIRFIELD SUITABLE FOR BIVOUAC AREA ABOUT 3 WOODED ACRES

8. UNDERGROUND SHELTER AVAILABLE NONE

9. DAMAGE CAUSED BY BOMBING AND DEMOLITION NONE EXCEPT AS PREVIOUSLY NOTED

10. SOIL TYPE & GEOLOGICAL DATA SANDY

11. HYDROLOGICAL CONDITION GOBOLOGASS RIVER ABOUT [illegible] MILE [illegible] AT AIRFIELD FLOWS TO PORT LONG BONGO NAVIGABLE BY RIVER

12. METEOROLOGICAL CONDITIONS PREVAILING WINDS SOUTHERLY BUT EXTREMELY LIGHT PRECIPITATION ABOUT 20 IN PER YR NO OUTSTANDING WET SEASON

13. CONSTRUCTION MATERIALS AND EQUIPMENT 20 CARLOADS OF CEMENT ON SIDING GRAVEL PIT ON OTHER SIDE OF RIVER FROM AIRFIELD

14. ADDITIONAL INFORMATION CHIEF OF VILLAGE LIVES NEAR AIRFIELD NATIVES UNFRIENDLY CHIEF SAYS PROBABLE SABOTAGE BY NATIVES OF VILLAGE

15. ANNEXES SEE ATTACHED SKETCH
 (Maps, photographs, sketches, overlays, soil samples)

16. SIGNATURE Lt J Parent
 (In charge of reconnaissance party)

LESSON 3

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

1. Air traffic imposes more severe design criteria than does vehicular traffic. In selecting an airfield site, what is the requirement of airfield reconnaissance as differing from that of road location reconnaissance? (frames 3-1 and 3-2)

2. The overall reconnaissance plan must be properly coordinated with all the various headquarters involved. Why is this important? (frame 3-6)

3. List the steps required in airfield reconnaissance. (frame 3-10)

4. Identify the major phases of a preliminary study explaining what is done in each. (frame 3-12)

5. What is the purpose of ground reconnaissance?

6. The prompt submission of reconnaissance reports is most essential. How can this requirement best be controlled? (frames 3-9 and 3-17)

7. In map reconnaissance, what should be the size (in miles) of circles marked on the map to identify existing airfields? (frame 3-20 and panel 3-1)

8. The fourth step in map reconnaissance is to identify and mark such obstruction as radio towers. What ratio, with respect to height, determines the diameters of circles for marking such obstructions? (frame 3-21 and panel 3-1)

9. The airfield siting template, when placed on a map, readily shows any land form and natural or manmade obstacles within the glide angle of tentative runway approaches. Using the example template (panel 3-2), what would be the maximum permissible height (in feet) of any obstructions within the approach zone for a glide angle of 40:1 at a distance of 6,000 feet? (frame 3-25 and panel 3-2)

10. In air reconnaissance, what is the function of the pilot and the engineer observer? (frames 3-27 and 3-28)

11. In reconnoitering a specific site from the air, what is the minimum number of passes made at 300 feet and at what height (in feet) is the final circuit usually flown? (frame 3-31 and panel 3-3)

12. A reconnaissance plane makes two passes in opposite directions, 50 yards on each side of the centerline, to estimate the length of a proposed runway. If the air speed is sustained at 100 mph and the average time of the two passes is 55 seconds, what is the estimated length in feet? (Assume wind is negligible.) (frame 3-31 and panel 3-3)

13. What activities should be conducted by both air and ground reconnaissance parties en route to the site to be investigated? (frames 3-29 and 3-34)

14. When a potential runway lies partially within a wooded area, describe the correct method to estimate the clearing and grubbing effort for the removal of trees. (frame 3-39)

15. When a final location is made for an airfield, in relatively flat country, at what intervals (in feet) are elevations checked? (frame 3-40)

16. In making a radio report concerning a tentative airfield site, how would the statement "glide angle is excellent" be transmitted? (frame 3-42 and panel 3-4)

17. What consideration controls the final selection of airfield sites? (frame 3-46)

18. Site requirements for Army airfields are less demanding than those for Air Force bases. For example, steeper slopes may be tolerated for Army runways; what would be the maximum change in grade (in percent) for a rear Army airfield? (frame 3-49 and panel 1-4)

19. Air reconnaissance of a potential airfield site reveals that a long straight road occupies the only favorable location for the runway. What action would be the most appropriate to take? (frame 3-51)

20. Freedom from interfering obstructions is a must for runway locations. Describe the minimum criterion pertaining to interfering obstructions. (frame 3-53)

21. Certain situations and layouts such as a ditch or pole line at the end of a runway are said to present a mental hazard to the pilot. What effect does the pilots reactions to such situations have on the effectiveness of the runway? (frame 3-54)

22. Meteorological conditions are an important criterion in final site selection. What agency of the Air Force maintains meteorological information for all populated areas of the world? (frame 3-55)

23. An ideal site is located on high ground, with sufficient slope for cross and longitudinal drainage, and a reasonably smooth surface requiring little earthwork. Which criterion of site selection determines the extent of drainage and earthwork required? (frame 3-58)

24. Explain the importance of examining hydrological conditions and consideration and soil characteristics. (frame 3-57 and 3-59)

25. What characteristic controls the thickness of the base course when required? (frame 3-59)

LESSON 4

LAYOUT PROCEDURES, CONSTRUCTION STAKING AND ALINEMENT

CREDIT HOURS ---------- 2

TEXT ASSIGNMENT ---- Attached Memorandum.

MATERIALS REQUIRED --- None.

LESSON OBJECTIVES

Upon completion of this lesson, you should in the following subjects areas, be able to:

1. **Control survey** — Discuss the value of bench marks in determining vertical and horizontal control.
2. **Use of construction stakes** — Describe the primary function of construction stakes; discuss their placement, the markings, and their meaning.
3. **Horizontal alinement** — Discuss the components, the seven principles in locating tangents, point of intersection (PI), point of tangency (PT), long chord, and hasty methods of staking curves.
4. **Vertical alinement** — Discuss the use of tangents for transition of vertical curves, the two types of parabolic curves (overt and invert), the point of vertical intersection (PVI), point of vertical curvature (PVC), point of vertical tangency (PVT), vertical curve offsets and eccentric curves.

CONTENTS

Set 1. Control Survey

FRAME 4-1.

Before layout work can begin on a road or airfield project, control must be established. The first step is to establish bench marks for vertical (1) ________ (elevations) and well-marked points for horizontal (2) ________________.

---

(1) ℄ (2) 15 + 00 (3) F (4) 2º (4-25)

FRAME 4-26.

The limits of the grading work must be clearly marked. Slope stakes are used to define the ________________ of ________________.

(principle) (4-50)

FRAME 4-51.

Keeping the number of tangents to a minimum will minimize the number of curves, provide long ________________ stretches, and improve route capacity.

(horizontal) (4-75)

FRAME 4-76.

The two processes, however, are closely related. An excellent horizontal alinement may be entirely unacceptable because of ______________ limitations.

(control) (control) (4-1)

FRAME 4-2.

Bench marks and (1) ________________ control points are frequently called hubs because of the short square stakes used. Hubs are normally 2" x 2" wooden stakes and are driven flush with the ground. The horizontal (2) ________ ____________ has a tack in its top to mark the exact point for angular and linear measurements.

(limits) (grading) (4-26)

FRAME 4-27.

In road work, ________________ stakes may also define the limits of clearing. Usually, the cleared area extends 6 feet beyond the slope stakes.

(straight) (4-51)

FRAME 4-52.

The number of tangents on any road project should be kept to a ____________.

(grade) (4-76)

FRAME 4-77.

The design process is necessarily a trial and error process until the design specifications of ____________________ and ____________________ alinements are met.

(1) horizontal (2) control hub (4-2)

FRAME 4-3.

The elevations of established bench marks are recorded and used as (1) ____________ ____________ points. The tack serves to mark the centerline or turning point for (2) ____________ control.

(slope) (4-27)

FRAME 4-28.

____________ stakes are set on lines perpendicular to the centerline (one on each side) at the points where the cut or fill slope intersects the ground surface and are tilted away from the centerline.

(minimum) (4-52)

FRAME 4-53.

Most roads constructed by the Army are supplements to an existing road net. Therefore, there normally will be intersections, or junctions at one or both ends of military roads. The connecting ________________ of new roads should approach at right angle junctions with existing roads.

(horizontal) (vertical) (4-77)

FRAME 4-78.

Gradelines must not exceed maximum grade specifications. If grade specifications are exceeded the facility would be useless, even though cuts and fills balance perfectly. Therefore, when setting gradelines never exceed ________________ ________________ ________________.

(1) vertical control (2) horizontal (4-3)

FRAME 4-4.

Control consists of a series of both vertical control points (or (1) ________ ________________) and (2) ________________ control points.

(slope) (4-28)

FRAME 4-29.

Slope stakes are located at the intersection of the cut or ________ slope and the ground ________.

(tangents) (4-53)

FRAME 4-54.

Location at ________ ________ to the old road improves operating efficiency and reduces traffic control problems.

(maximum) (grade) (specifications) (4-78)

FRAME 4-79.

Problems such as undesirable soil or water table level must also be considered (solved) in setting the final grade. These physical problems must be ____________ in terms of economy of construction and a safe and usable facility.

(1) bench marks (2) horizontal (4-4)

FRAME 4-5.

Vertical control can be established by determining the actual ____________ of the bench marks if this is convenient. However, this is not normally done in military construction.

(fill) (surface) (4-29)

FRAME 4-30.

The slope stakes are placed at certain intervals. (1) ________________ stakes are set at 100-foot (2) ________________ on tangents, 50-foot intervals on curves, and at sharp breaks in the ground profile.

(right angles) (4-54)

FRAME 4-55.

As we have seen, long tangents are desirable. The most common hindrance to long ________________ is some vertical obstacle such as a hill, with excessive grades.

(solved or considered) (4-79)

FRAME 4-80.

Grade limitations and limiting characteristics of the ________________ must be solved in terms of ________________ of construction of a usable facility.

(elevation) (4-5)

FRAME 4-6.

In establishing vertical control, an easily found (1) __________ __________ will usually be designated as having an assumed (convenient) elevation such as 100′, 1,000′ and so forth. All other (2) __________ on the project are tied into the datum of this established bench mark system.

---

(1) slope (2) intervals (4-30)

FRAME 4-31.

Slope stakes should be set at (1) __________ - foot intervals in tangents, at (2) __________ __________ - foot intervals in curves, and at (3) __________ __________ in the ground profile.

(tangents) (4-55)

FRAME 4-56.

The engineer, when locating tangents, must consider the ability of the construction force to construct the facility within allowable grade limitations. Tangents should be selected which will avoid excessive ______________ and thus keep earthwork to a minimum.

(terrain) (economy) (4-80)

FRAME 4-81.

Following placement of a series of gradelines, the road or airfield is defined vertically in a series of tangents between points of vertical intersection. Points of vertical intersection are connected by means of ______________.

(1) bench mark (2) elevations (4-6)

FRAME 4-7.

Vertical control is generally established by selecting a convenient bench mark as a ________________ and referencing all other elevations to it.

---

(1) 100 (2) 50 (3) sharp breaks (4-31)

FRAME 4-32.

The front of a slope stake is the side facing the centerline. Therefore, the ________________ of the slope stake is visible from the centerline.

(grades) (4-56)

FRAME 4-57.

At the intersection of two tangents it is necessary to establish an easement or curve from one tangent to the other. To join such tangents two types of ____ ________ are commonly used the circular curve and the spiral curve.

(tangents) (4-81)

FRAME 4-82.

A transition providing a smooth easy movement from one ________ to the next must be provided. This is done by utilizing a vertical curve.

(datum) (4-7)

FRAME 4-8.

Horizontal ________________ points may be tied into a local grid system if one is readily available.

(front) (4-32)

FRAME 4-33.

The amount of cut or fill, at that location, needed to bring to finished grade at the edge of the shoulder is marked on the front of the stake. On a slope stake, C4º would appear on the ________________.

(curves) (4-57)

FRAME 4-58.

For military roads and design speed, the circular curve (panel 4-5) is adequate and easier to design and construct. Therefore, in military construction ________________ curves are normally used.

(tangent) (4-82)

FRAME 4-83.

The ________________ ________________ used to provide this smooth movement from one tangent (grade) to the next is usually parabolic in form.

(control) (4-8)

FRAME 4-9.

Usually, well marked (1) ______________ are tied into the grid network and all (2) ______________ distances are measured relative to it.

(front) (4-33)

FRAME 4-34.

Also on the ______________ of the slope stake is written the distance from the centerline.

(circular) (4-58)

FRAME 4-59.

The point where two tangents intersect is called the point of intersection (PI). and the exterior angle is the angle of intersection (I). This is also the angle subtended between the intersection of the radius points at 0 (see panel 4-5). The point where two tangents intersect is called the (1) ______________ of ______________ (abbreviated __________) and the exterior angle between them is the (2) ______________ of ______________ (abbreviated __________).

(vertical curve) (4-83)

FRAME 4-84.

In addition to the smooth transition provided by a ______________ curve, another advantage is that its essential dimensions can be easily calculated by the surveying crew in the field.

(1) points (2) horizontal (4-9)

FRAME 4-10.

Location of control points is important to prevent damage to them. Both horizontal control points and bench marks should be placed well out of the construction zone to (1) ______ _____ them against accidental (2) ____________.

(front) (4-34)

FRAME 4-35.

On the back of the slope stake, the station numbers and the slope ratio of the cut or fill are written. If a slope stake is located at the edge of a cut, the letter ________________ would precede the amount of cut necessary from the slope stake to the edge of the road shoulder.

(1) point of intersection (PI) (2) angle of intersection (I) (4-59)

FRAME 4-60.

The point where the curve begins or leaves the tangent is called the point of curvature (PC) and the point where the curve joins the tangent or where the curve ends is called the point of tangency (PT) (panel 4-5). The point where a curve begins is the (1) ______ ______ of ______ (abbreviated ______) and the point where a curve ends is the (2) ______ ______ of ______ (abbreviated ______).

(parabolic) (4-84)

FRAME 4-85.

Two types of parabolic curves are used. The overt (convex) curve is used to curve over a hill. The invert (concave) curve is used to provide transition from a down grade to an ______ or to a level alinement (tangent).

(1) protect (2) damage or destruction (4-10)

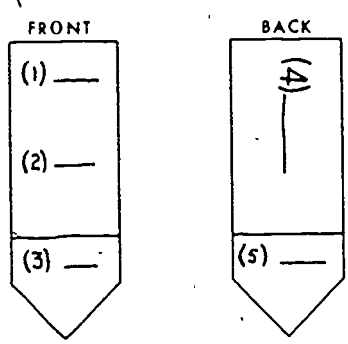
FRAME 4-11.

We will now consider the uses and functions of construction stakes. The primary function of ________________ stakes is to indicate the alinement of a construction facility, to aid equipment operators, to control specifications, and to prevent excessive work.

C (4-35)

FRAME 4-36.

A stake placed and marked as the one shown in panel 4-2 (page 4-53) would mean—that it was a slope stake marking the point where a 1:1 cut slope intersects the natural ground surface 25.5 feet from the centerline, 7800 feet from the origin, and indicating a cut of 4.0 feet in relation to the edge of the shoulder. How would a slope stake where a 3-foot fill (1½:1 slope) is necessary, occurring 1500 feet from origin, and 20 feet from the centerline be marked?



(1) point of curvature (PC) (2) point of tangency (PT) (4-60)

FRAME 4-61.

The standard circular curve, usually used in military construction, is an arc of a circle. The radius of the circle, or the distance from the curve to the center of the circle is referred to as the **radius** (R) or radius of curvature (panel 4-5). The distance from the curve to the center of the circle of which it is a part is referred to as the ________________ (abbreviated ________________).

(upgrade) (4-85)

FRAME 4-86.

The two types of parabolic curves are: ____________ and ____________.

(construction) (4-11)

FRAME 4-12.

The information necessary to construct a given facility must be written on properly placed (1) ______________________ at the site. This information indicates the (2) ______________________ of the construction facility, aids equipment operators, controls specifications, and helps to prevent ______________________.

---

(1) F (2) 3° (3) 20°' (4) 15 + 00 (5) 1½:1 (4-36)

FRAME 4-37.

As soon as grading work is started, centerline stakes will usually be destroyed by earthmoving equipment and many ______________________ stakes will be removed.

(radius (R)) (4-61)

FRAME 4-62.

The distance from the PI to the PT or from the PI to the PC is known as the **tangent** distance (T). The distance from the PI to the mid-point of the curve is referred to as the external distance (E) (refer to panel 4-5). The (1) ______________ ______________ (abbreviated ______________) is the distance from the PI to the PT or from the PI to the PC. The (2) ______________ ______________ (abbreviated ______________) is the distance from the PI to the midpoint of the curve.

(overt) (invert) (4-86)

FRAME 4-87.

The overt parabolic curve is ______________ in form, the invert parabolic curve is ______________ in form.

(1) construction stakes (2) alinement, excessive work (4-12)

FRAME 4-13.

Construction stakes include centerline, slope, ditch, offset, reference, grade, and intermittent stakes and bench marks. Construction ________________ is written on these ________________.

(slope) (4-37)

FRAME 4-38.

In order to eliminate resurveying portions of the road or airfield, offset stakes are placed beyond construction limits and are used to ________________ centerline and slope stakes.

(1) **tangent distance (T)** (2) **external distance (E)** (4-62)

FRAME 4-63.

The straight line distance from the PC to the PT is known as the **long chord** (C). The distance from the mid-point of the long chord to the midpoint of the curve is referred to as the middle ordinate (M). The straight line distance from the PC to the PT is the ______________ ______________ (abbreviated ______________).

(convex) (concave) (4-87)

FRAME 4-88.

Panel 4-7 illustrates a typical vertical curve installed between two intersecting ______________ lines.

(information) (stakes) (4-13)

FRAME 4-14.

Stakes on which the ________________ information is written should be made from lumber approximately 1″ by 3″ by 2′ in size. In the absence of stakes, small trees blazed on both sides and cut to length may be used.

(relocate) (4-38)

FRAME 4-39.

Located beyond construction limits, ________________ stakes are set on a line at right angles to the centerline and in alinement with slope stakes.

long chord (C) (4-63)

FRAME 4-64.

The ______________ ______________ (abbreviated __________) is the distance from the midpoint of the curve to the midpoint of the long chord

---

(grade) (4-88)

FRAME 4-89.

The intersection point of two tangent grade lines is referred to as the point of vertical intersection (PVI). Where two tangent grade lines meet is the ______________.

(construction) (4-14)

FRAME 4-15.

Construction stakes are usually placed by a surveying crew and they contain ________ ________________.

(offset) (4-39)

FRAME 4-40.

Slope stakes are relocated first. The centerline stake is then readily relocated by measuring the horizontal distance indicated on the ________________ stake.

(middle ordinate (M)) (4-64)

FRAME 4-65.

The distance from the PC to the PT along the curve, measured as a series of 100-foot chords is known as the length of curve (L). Therefore, L is the (1) ____________ ________ ____________ from PC to PT measured in (2) ____________ - ________ ____________.

(PVI) (4-89)

FRAME 4-90.

The point of vertical curvature (PVC) and the point of vertical tangency (PVT) are the points where the curve leaves the grade line and joins the grade line respectively. T. ~ PVC 's the point where the curve ________________ the grade line.

(control) (specifications) (4-15)

FRAME 4-16.

Centerline or alinement stakes are placed on the ______________ of a road or airfield to indicate its location, ______________, and direction.

(relocated) (slope) (4-40)

FRAME 4-41.

Offset stakes contain all the information on the original slope stake plus the horizontal distance from the slope stake to the offset stake. This **offset** distance is on the stake and is circled to indicate that it is the ______________ distance from the slope stake.

(1) length of curve (2) 100-foot chords (4-65)

FRAME 4-66.

The angle subtended by one of the 100-foot chords is the degree of curvature (D) (see panel 4-6). The degree of curvature is the _______ subtended by one of the ______________________.

(leaves) (4-90)

FRAME 4-91.

The PVT is the point where the curve ______________ the grade line.

(centerline) (alinement) (4-16)

FRAME 4-17.

Centerline or alinement stakes are the first stakes to be placed and are located accurately because they are used as ____________________ points in locating other stakes.

(offset) (4-41)

FRAME 4-42.

An offset stake set at 20 feet from the slope stake shown in panel 4-2 would be marked as shown in panel 4-3. Note that the horizontal distance 20⁰′, from the slope stake to the offset stake is circled to indicate that it is (1) ____________ ____________________. If the offset distance was 25 feet, this information would then be shown as (2) ____________________.

(angle) (100-foot chords) (4-66)

FRAME 4-67.

The distance along a curve, measured as a series of 100-foot chords, is the (1) ________________ of ________________ (________). The angle subtended by one of these 100-foot chords is the (2) ________________ of ________________ (________).

(joins) (4-91)

FRAME 4-92.

The point where two gradelines or tangents intersect is the (1) ________ and the points where the curve leaves and joins the gradelines are the (2) ________________ and the (3) ________________ respectively.

(control or reference) (4-17)

FRAME 4-18.

(1) ________________ stakes are normally placed at 100-foot intervals except that on irregular terrain they may be placed (2) ________________ together for better control.

---

(1) offset distance (2) 25' (4-42)

FRAME 4-43.

There are many other types of construction stakes such as shoulder stakes, reference stakes, and grade stakes, which may be used under special conditions (particularly airfield runways) requiring greater control of work. The engineer may use any special type ________________ that he thinks necessary to adequately ________________ a construction project.

171

(1) length of curve (L) (2) degree of curvature (D) (4-67)

FRAME 4-68.

When hasty type roads and airfields are built in forward areas, high precision is not essential, a fairly good curve can be staked in by the eye and then adjusted as construction proceeds. Therefore, in this situation, horizontal curves are usually laid out ________ ________.

---

(1) PVI (2) PVC (3) PVT (4-92)

FRAME 4-93.

Grades are expressed in percentages (rise of grade in feet/100 feet). The percentage of grade at the grade tangent nearest the point of origin is normally referred to as G_1 and the other grade tangent is referenced as G_2 (panel 4-7). G_1 is the tangent ________________ the point of origin.

(1) centerline (2) closer (4-18)

FRAME 4-19.

The placement of centerline stakes on the centerline is our next concern. To easily read the information on them, centerline stakes are placed with the broad side of the stake ________________ to the centerline.

Set 3: Horizontal Alinement

(stake) (control) (4-43)

FRAME 4-44.

As we have seen (sets 1 and 2), control is first established and then alinement is projected by means of construction stakes. The engineer must determine the best horizontal and vertical positioning of the facility. The horizontal and vertical positioning of the facility is called ____________________________.

(by eye) (4-68)

FRAME 4-69.

Another simple way of staking out a curve in a forward area would be to have the driver of a grader or a truck make a gradual turn and use the wheel tracks to ______________ ______________ the curve.

(nearest) (4-93)

FRAME 4-94.

The offset distance from the PVI to the curve is the longest offset on the curve and is referred to as the maximum offset (MO). Offset distances from the tangents to the curve at various distances along the curve are known as offsets O. The offset distance from the PVI to the curve is the ______________ ______________ (abbreviated ______________).

(perpendicular) (4-19)

FRAME 4-20.

The side of the ________________ stake which faces the starting point is designated as the front of the stake and is marked with the centerline symbol ℄ and as applicable PC for point of curvature or PT for point of tangency.

(alinement) (4-44)

FRAME 4-45.

There are two types of alinement to be considered in locating a road or an airfield, ________________ alinement and vertical ________________.

(stake out) (4-69)

FRAME 4-70.

Another type of curve used in road alinement is the compound curve. Compound curves consist of two or more circular curves of radii which join together to form larger curves. These curves may be used to curve around obstacles where it is not feasible to use one curve. When two curves of different radii are thus formed together, the curve which is formed is a ______ ______ ______________.

(maximum) (offset) (MO) (4-94)

FRAME 4-95.

The length of a vertical curve (L) is the horizontal distance between the PVC and the PVT (panel 4-7). The actual distance along the curve is not considered. The PVI is located midway between the PVC and the ________________.

(centerline) (4-20)

FRAME 4-21.

Also marked on the (1) ______________ of the stake is the distance from the origin and the fractional part of a station, if such is used. A stake which was marked 18 + 26[12] would be 1826.12 feet from the beginning of the facility. A stake marked 21 + 25[05] would be (2) ______________ feet from the beginning.

(horizontal) (alinement) (4-45)

FRAME 4-46.

We will first discuss horizontal alinement. Horizontal alinement consists of a series of straight lines called tangents connected by horizontal curves. In looking at the horizontal alinement of a road on a map, we would see that it consisted of a series of ______________ connected by ______________.

(compound) (curve) (4-70)

FRAME 4-71.

Both curves of a ________________ ________________ may curve in the same direction or in opposite directions. In the latter case, they are known as reverse curves.

(PVT) (4-95)

FRAME 4-96.

The curve length is the horizontal distance from PVC to ______________.

(1) front (2) 2125.08 (4-21)

FRAME 4-22.

On the back of the centerline stake, the information on cut (C) or fill (F) required at each ________________ is written.

(tangents) (curves) (4-46)

FRAME 4-47.

In the preparation of (1) ________________ alinement, intersecting tangents are first laid out (panel 4-4) and are later connected by curves. Therefore, in the horizontal alinement of a road, we are first concerned with the straight lines or (2) ________________.

(compound) (curve) (4-71)

FRAME 4-72.

When the curves of a compound curve turn in opposite (reverse) directions, they are called ______________________.

(PVT) (4-96)

FRAME 4-97.

The curve described in the preceding discussion was the standard vertical curve. Another type curve, the eccentric curve is used when one of the grade tangents (G_1 or G_2) is longer than the other and PVI is not in the center of the curve. The two types of vertical curves are standard and ______________.

(station) (4-22)

FRAME 4-23.

The letter C is used to indicate ________________ and the letter F to indicate ________________.

---

(1) horizontal (2) tangents (4-47)

FRAME 4-48.

Each tangent must be stationed or sufficient information obtained as to azimuth and distances so that horizontal ________________ can be adjusted and necessary designs accomplished.

(reverse) (curves) (4-72)

FRAME 4-73.

We will now discuss the vertical alinement of roads and airfields. Vertical alinement of roads and airfields is that portion of the design process that is concerned with the establishment of grades and the determination of the vertical connecting curves between these grades. The establishment of grades and vertical curves is ________________ ________________.

(eccentric) (4-97)

FRAME 4-98.

When one grade tangent is longer than the other the ________________ curve should be used.

(cut) (fill) (4-23)

FRAME 4-24.

The centerline symbol is written ________________.

(alinement) (4-48)

FRAME 4-49.

(1) ____________________ must be stationed or information obtained about them to enable (2) ____________________ of alinement and necessary designs.

(vertical) (alinement) (4-73)

FRAME 4-74.

The grades must be kept within desirable criteria and specifications. The curves between the grades must provide gradual transfer from one ________ to the next.

(eccentric) (4-98)

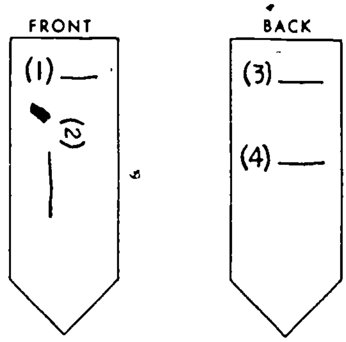
FRAME 4-99.

In hasty construction, it is often necessary to build vertical curves without calculations or staking. When this becomes necessary, the engineer must insure that the resulting curve provides a ________ ________ ________ between tangents (grades).

℄ (4-24)

FRAME 4-25.

A stake placed and marked as the one shown in panel 4-1 (page 4-53) would mean that it was a centerline stake 2600 feet from the origin and that a 4.0-foot cut was necessary at that point. How would a centerline stake 1500 feet from the origin where a 2.0-foot fill was necessary be marked?



Turn back to bottom of page 4-3.

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(1) tangents (2) adjustment (4-49)

FRAME 4-50.

There are several principles to be observed when locating tangents. The first _______________ is that the number of tangents should be kept to a minimum.

Turn back to top of page 4-4.

(grade) (4-74)

FRAME 4-75.

The vertical alinement of a road or airfield is normally accomplished after the __________ alinement has been completed.

Turn back to bottom of page 4-4.

(smooth) (easy) (transition) (4-99)

FRAME 4-100.

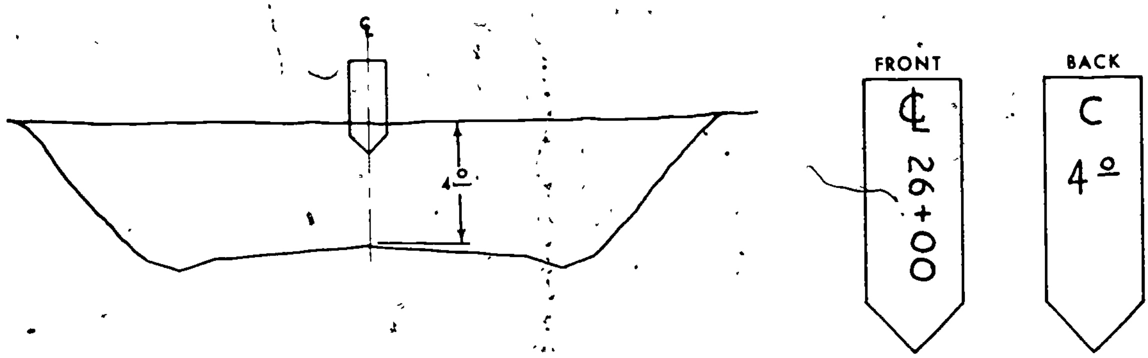
In hasty construction, curves must, therefore, meet minimum __________, but they may be constructed without elaborate calculations and __________.

(specifications) (staking) (4-100)

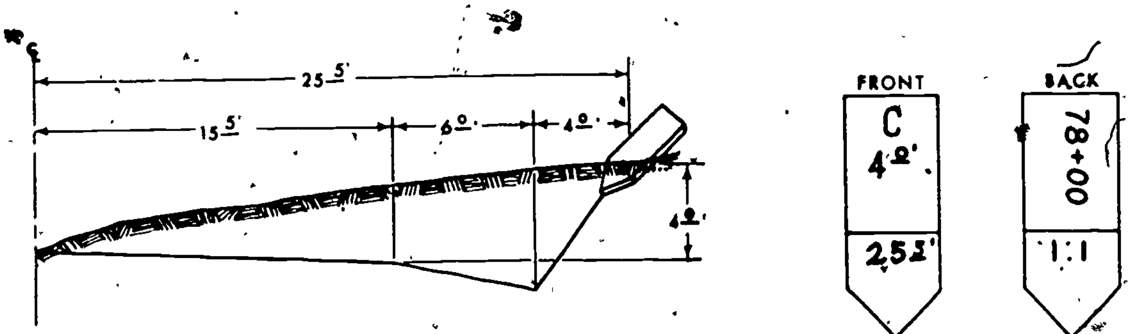
END OF FRAMES

PANELS AND SELF TEST FOLLOW

Panel 4-1. Marking of Centerline Stake.

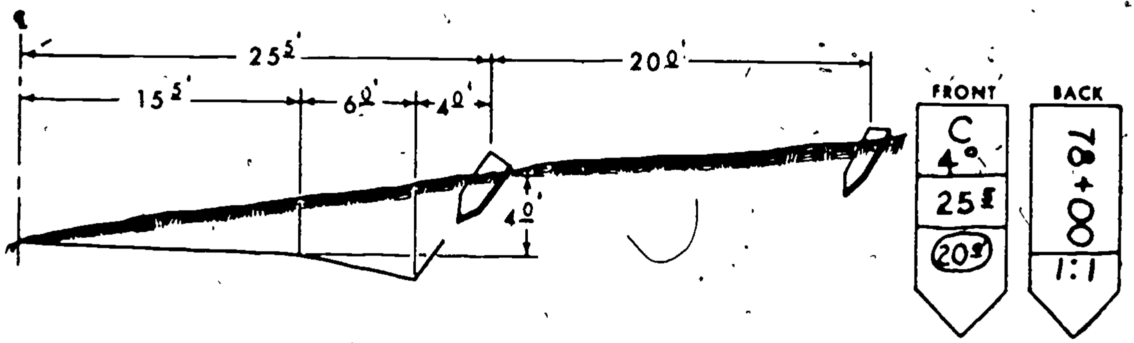


Panel 4-2. Marking of Slope Stake for Standard 2-Lane Road.

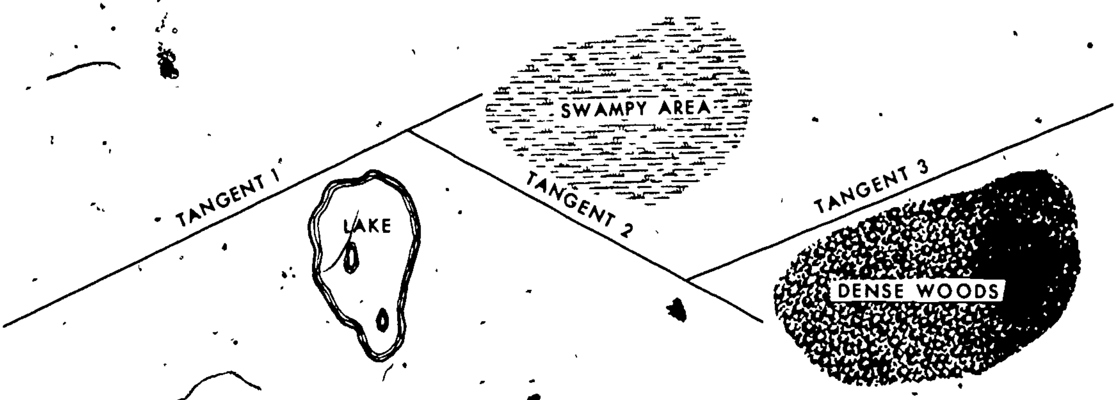


DISTANCE FROM CENTERLINE=HALF THE ROADBED+6 DITCH+4×1
=15.5+6+4=25.5'

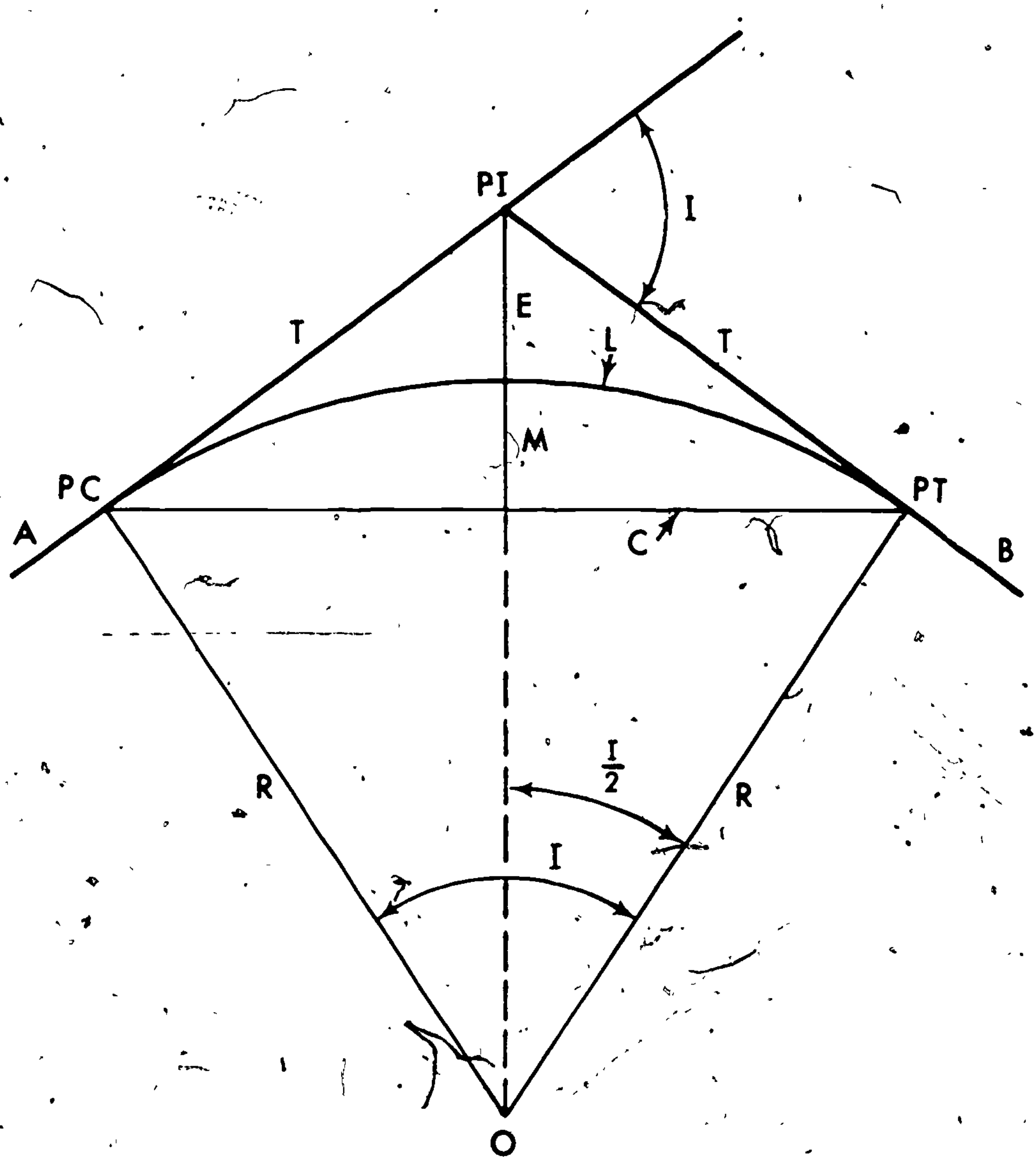
Panel 4-3. Marking of Offset Stake.



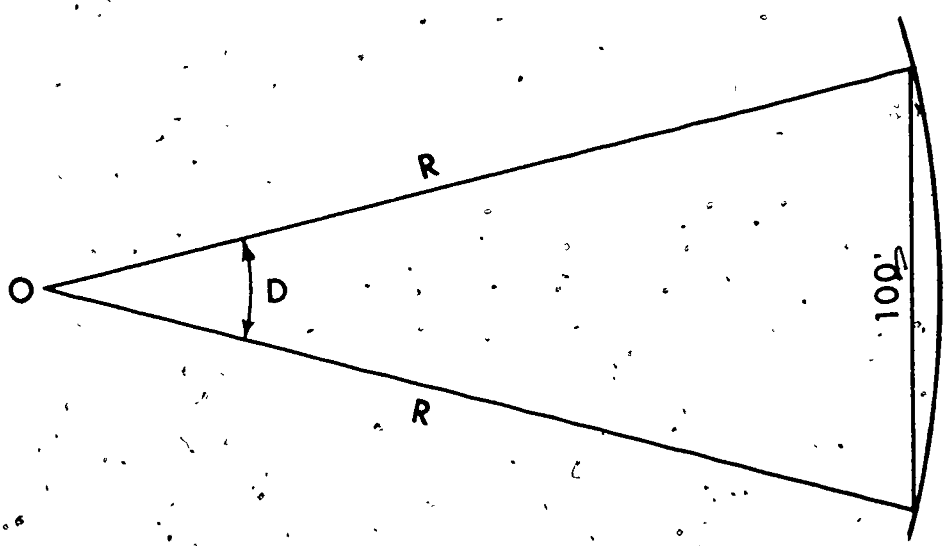
Panel 4-4. Horizontal Alinement—Tangent Layout.



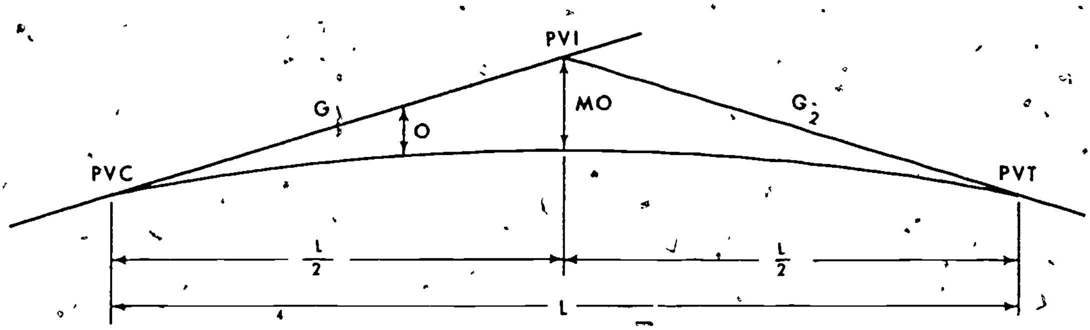
Panel 4-5. Simple Horizontal Curve—Circular.



Panel 4-6. Degree of Curvature—Chord Definition.



Panel 4-7. Parts of a Vertical Curve.



LESSON 4

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

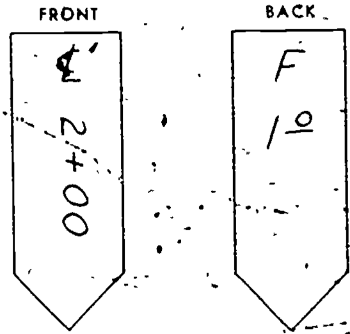
1. In the normal construction sequence, establishment of control is required before any work can begin. Define control establishment and tell how it is accomplished. (frame 4-1 to 4-8)

2. Explain the primary function of construction stakes. (frame 4-11)

3. Give the purpose of the centerline or alinement stakes. (frame 4-16)

4. Describe the information which is contained on centerline stakes. (frames 4-20 to 4-22)

5. Describe in complete detail, all the information given on the construction stake below: (frame 4-25)



____

____

____

6. What is the purpose of slope stakes? (frame 4-26)

____

____

____

7. Draw and properly mark a slope stake marking the point where a 1½:1 cut slope intersects the natural ground surface 27.5 feet from centerline, 2300 feet from the origin, and indicates a cut of 2.5 feet with respect to the shoulder. (frame 4-36)

____

____

____

8. Explain the purpose of offset stakes. (frames 4-38, 4-39, 4-41, 4-42)

____

____

____

9. Define horizontal alinement. (frame 4-46)

10. Give three principles of horizontal alinement. (frame 4-50, 4-53, 4-56)

11. Define PI, angle of intersection, PC, and PT. (frame 4-59, 4-60)

12. Describe two methods of staking out a curve in a forward area. (frames 4-68, 4-69)

13. When does a compound curve become a reverse curve? (frame 4-71)

14. Define vertical alinement. (frame 4-73)

15. What type curve is normally used in vertical curves? (frame 4-83) Why is it preferred? (frame 4-84)

16. Explain the difference between the two types of parabolic curves. (frames 4-85 to 4-87)

17. What do the following abbreviations stand for? (frames 4-89, 4-90, 4-91)

(a) PVI

(b) PVC

(c) PVT

LESSON 5

EARTHWORK ESTIMATES AND MASS DIAGRAM

CREDIT HOURS ------------2

TEXT ASSIGNMENT ------Attached Memorandum.

LESSON OBJECTIVES

Upon completion of this lesson, you should, in each of the following subject areas, be able to:

1. **Factors influencing earthwork estimates** — Discuss the purpose of earthwork computations and factors which influence them.
2. **Hasty estimate method** — Compute volumes of earthwork using available volume tables.
3. **Cross section method** — Calculate cross sectional areas by the most widely used method (cross section method) which includes two variations: (1) counting the squares and (2) triangle method.
4. **Average end area method** — Calculate volumes by the formulas of the end area method, know the limitations of the formulas, and use earthwork tables to use as alternate means in volume computations.
5. **Airfield earthwork volumes** — Use special airfield earthwork tables to calculate volumes by average-end-area method and explain the significance of the cut to fill factor.
6. **Establishing runway gradeline by profile method** — Establish tentative gradelines early in construction to avoid unnecessary delays and allow heavy equipment to begin working.
7. **Computing borrow pit volumes** — Compute borrow pit volumes by two different methods.
8. **Mass diagram** — Describe the mass diagram and state its function, value, and use to include volume changes (shrinkage and swell) of soil.
9. **Plotting the mass diagram** — Explain the actual development of the mass diagram; the significance of the various patterns formed by mass lines; and the computation of net yardage, total yardage, borrow, and waste from the mass diagram.
10. **Selection of equipment by use of mass diagram** — Discuss the method by which the suitable equipment can be chosen for a certain length of haul and estimate requirements for time and personnel.

CONTENTS

Set 1. Factors Influencing Earthwork Estimates

FRAME 5-1.

Earthwork computations are the calculations of earthwork volumes or quantities in order to determine final grades, to balance cut and fill, and to plan the most economical haul of material. The purposes of earthwork computations are to furnish final grades, to balance ________________ and ________________, and to plan the most economical ________________ of material.

---

(700) (41.30) (5-30)

FRAME 5-31.

The sum of the two figures (41.30) and (700) gives 741 (nearest whole number). This is the ________________ in cubic yards between the stations.

(excavation) (embankment) (5-60)

FRAME 5-61.

The mass diagram is used to determine the most economical distribution of materials. Since the amount of excess material between any two points can be determined, a careful study of the mass diagram will show where it will be expedient to waste material and borrow closer to the area to be filled. The mass diagram would aid in determining when to ________________ material and ________________ closer to the area to be filled.

(elevations) (convenient) (5-90)

FRAME 5-91.

Entries from column 10 (ordinates) are plotted as ordinates and the centerline survey stations as abscissas in constructing the ________________ ________________.

(cuts) (fills) (hauls) (5-1)

FRAME 5-2.

Materials to be imported and mixed with subgrade soils for subgrade stabilization are included in earthwork computations, but base course or paving materials to be placed above the subgrade are not included. Subgrade materials are included in the computations; base course materials are ________________ ________________.

(volume) (5-31)

FRAME 5-32.

For distances between stations (cross sections) other than 100 feet, multiply the result obtained by the distance and divide by 100. Should the sum of the end areas be greater than 1673.9, break up the sum into portions that will fit the table and add the results to get the total ________________.

(waste) (borrow) (5-61)

FRAME 5-62.

In making the decision to borrow, the work involved in opening and closing a borrow pit, and in wasting excess material, must be balanced against the decreased yardage output of the same equipment at longer hauls. Decreased yardage output in longer hauls must be balanced against the work of opening and closing a ______________ ______________ and wasting ______________ ______________.

(mass) (diagram) (5-91)

FRAME 5-92.

An ascending mass line in the diagram indicates an excess of excavation, and a descending mass line an excess of fill along the portion of the area for which the mass diagram is drawn. An ascending mass line indicates an (1) ______________ of ______________, a descending line an (2) ______________ of ______________.

(not included) (5-2)

FRAME 5-3.

When topsoil or unsuitable material is stripped from cut and fill areas and placed outside the slope stake limits, cut and fill quantities affected must be converted (compensated) for the loss of material. Stripping of undesirable material must be ________________ for in cut and fill estimates.

Set 5. Airfield Earthwork Volumes

(volume) (5-32)

FRAME 5-33.

Because runways normally are much wider than roads, earthwork quantities are estimated from special tables of centerline cut and fill depths and corresponding volumes. These tables are prepared as shown in Panel 5-4. Estimates of runway earthwork require the preparation of (1) ____________ ____________. This is because runways are normally much (2) ________________ than roads.

202

(borrow pit) (excess) (material) (5-62)

FRAME 5-63.

When there are both cut and fill volumes between stations, the mass diagram shows only the volume of earth necessary to complete the balance. The volume of earth necessary to ______________ the ______________ is shown in the mass diagram.

---

(1) excess excavation (2) excess fill (5-92)

FRAME 5-93.

When the mass line forms summit humps, the haul will be from the lower to the higher station numbers, when the mass line forms sag humps, the haul will be from the higher to the lower station numbers. Summit humps in the mass line indicates that the haul will be from the (1) ______________ to higher station numbers. Sag humps indicate the haul will be from the (2) ______________ to the lower stations.

(compensated) (5-3)

FRAME 5-4.

The accuracy with which earthwork estimates are made is dependent upon the precision of field measurements during the preliminary survey and final location. Accuracy of field measurement determines the accuracy of ______________________________.

---

(1) special tables (2) wider (5-33)

FRAME 5-34.

A table for each site is necessary as minor differences in transverse ground slopes and typical cross sections seriously affect the quantities of cut or fill in 100 feet of runway ______________.

(complete) (balance) (5-63)

FRAME 5-64.

Where cut and fill volumes balance between two stations, the mass diagram may show ______________ ______________ ______________

necessary. Earthwork sheets should be used with the mass diagram in determining equipment requirements.

---

(1) lower (2) higher (5-93)

FRAME 5-94.

The balance line is a horizontal line between any two points on the mass line where excavation equals embankment. The maximum length of the balance line is predetermined on the basis of an efficient haul. Two points on the mass line between which excavation and embankment are equal are connected by a

______________________________.

(earthwork). (estimates) (5-4)

FRAME 5-5.

The precision of field measurements should be consistent with construction requirements. Sometimes the tactical situation dictates hasty estimates in which case (1) ________________ measurements would be a waste of effort. When time is vital, or the type of construction is of low order, (2) ________________ estimates of earthwork would suffice.

(length) (5-34)

FRAME 5-35.

In runway construction, minor differences in ________________ ________________ slopes and typical cross ________________ seriously affect quantities of cut and fill.

(no earth) (haul) (5-64)

FRAME 5-65.

Panel 5-6 pertains to frames 5-65 through 5-74. Note that the tabulations for computing earthwork volumes and preparing the mass diagram are entered on such a computation sheet. Column 1 lists the ______________ and ______________ ______________ are listed in column 2.

(balance line) (5-94)

FRAME 5-95.

The length of a balance line is determined by the length of an efficient ______________.

(precision) (hasty) (5-5)

FRAME 5-6.

Earthwork can be estimated with only the centerline plotted and the grade established. The average depth of cut or height of fill between 100-foot stations is estimated and the volume of material is then read from a volume table (panel 5-1). Plotting of ________ and establishment of ________ enable the use of a volume table.

(transverse) (ground) (sections) (5-35)

FRAME 5-36.

Quantities for the table are calculated by obtaining cross section areas and determining ________ by the average-end-area method.

(stations) (end areas) (5-65)

FRAME 5-66.

Cut and fill volumes, in cubic yards, are entered in column ______________. The quantity of excavation or embankment entered opposite each station is the volume between that station and the next succeeding station.

(haul) (5-95)

FRAME 5-96.

The assumed efficient haul distance in panel 5-8 is 1,000 feet. BJ and KM are ________________ ________________ whose length is equal to efficient haul.

(centerline) (grade) (5-6)

FRAME 5-7.

Required: Cubic yards per 100 feet of cut, 30 feet wide at the base, with 1½ to 1 side slopes and an average depth of 5 feet. Entering the table (Panel 5-1) at 5 feet in column 1 and continuing horizontally to column 8, the value for a 30-foot cut with 1 to 1 slopes is found to be ________________ yards.

(volumes) (5-36)

FRAME 5-37.

Tables may be prepared for various ________________ ground slopes and ________________ cross sections by the unit surveying section during slack periods for use when needed.

3 (5-66)

FRAME 5-67.

For example, the figure 537 in column 3 opposite station 28 + 100 means that there are ________________ cubic yards of excavation between stations 28 + 00 and ________________________.

(balance lines) (5-96)

FRAME 5-97.

Balance lines are drawn (1) ________________ to the datum line so as to intersect the mass diagram at two points, called balance points. The excavation between B and J, D and F, F and H, and K and M is exactly equal to the embankment and all haul is within limits of (2) ________________ haul.

648 (5-7)

FRAME 5-8.

Continuing horizontally, column 11 indicates that ______________ yards must be added when the slopes are $1\frac{1}{2}$ to 1.

(average) (typical) (5-37)

FRAME 5-38.

The table includes the maximum range of cut and fill for the site. By scaling the interval of cut or fill between the ground profile and the ______________ ______________ at each station from the sketch plans, the quantity of earthwork is obtained directly from the appropriate ______________ ______.

(1) 537 (2) 29 + 00 (5-67)

FRAME 5-68.

Note that both fill and cut are encountered at most stations in the table. This means that most sections on this particular project are side-hill sections. Station, 33 + 00 would be an ______________________.

---

(1) parallel (2) efficient (5-97)

FRAME 5-98.

Between the two points where the balance line intersects the mass line, excavation ________________ embankment.

FRAME 5-9.

The calculation is as follows: 648 + 46 = 694 yards of cut for every ________ feet of length. Volumes in table are "in-place" volumes.

(grade line) (table) (5-38)

FRAME 5-39.

The intervals of cut and fill between the ground profile and the grade line are (1) ________ from the sketch and the quantity of earthwork involved found by application of the table. Summation of the tabulated quantities gives the total (2) ________ to be handled.

(exception) (5-68)

FRAME 5-69.

Stripping volume, in cubic yards, is entered in column 4. This normally represents one of two things: the volume of topsoil or similar material which is stripped and saved for later use, as in a cut section or the volume of unsuitable material which is to be stripped and wasted, as in an embankment section. Stripping volume may consist of either material to be ________________ for later use or unsuitable material which is stripped and ____________________.

(equals) (5-98)

FRAME 5-99.

In addition to the factors discussed above, the placing of balance lines is affected by the shape and number of the lobes of the mass diagram (refer to line DFH in panel 5-8). If this line is (1) ________________ above its present position, it would result in a greater quantity of overhaul. It would extend beyond the points on the (2) ________________.

Set 3. Cross Section Method

100 (5-9)

FRAME 5-10.

The cross section method of computing earthwork volumes is the most widely used method in both road and airfield construction. The method we are about to consider is called the ______ ______ method.

---

(1) scaled (2) volume (5-39)

FRAME 5-40.

In Panel 5-4, the factor of cut to fill is based on 125 cubic yards of excavation required to make 100 cubic yards of fill, for fills 2 feet high and under (100/125 $\doteq$ 0.8). The factor of cut to fill is 125 cubic yards of fill for fills ______ feet high and under.

(saved) (wasted) (5-69)

FRAME 5-70.

In the project tabulated in panel 5-6, stripping begins at station ________ because the work involved the extension of an existing field.

---

(1) placed (2) mass line (5-99)

FRAME 5-100.

Placement of this (DFH) below its present position also would not be economical since a portion of the haul would then ________________ the limit of efficient haul. Each mass diagram must be given careful study to determine the most efficient placement of every balance line.

(cross) (section) (5-10)

FRAME 5-11.

After the position of the subgrade line and the shape of the typical cross section are established, cross sections are plotted for each 100-foot station on the adopted centerline in runway construction, and for each 100-foot station on tangents and every 50 feet on curves in road and taxiway construction. The position of the ______________ line and the shape of the typical ______________ ______________ are first established.

---

2 (5-40)

FRAME 5-41.

For fills over 2 feet high, the factor is 0.85. Cut volume times factor (0.8 or 0.85) gives volume of ______________.

32 + 20 (5-70)

FRAME 5-71.

Note that in obtaining the volumes under column 5, the stripping volume (column 4) is subtracted from the quantity of excavation entered in column 3. This is because the volume of excavation of column 3 will (1) ______________ be used in making the fill. Excavation volume minus (2) ______________ volume equals fill volume.

(exceed) (5-100)

FRAME 5-101.

The points of maximum embankment and excavation on the mass diagram are approximately the stations at which the ground line crosses the __________ ____________________ on the profile.

(subgrade) (cross section) (5-11)

FRAME 5-12.

Cross sections are plotted for each __________-foot station on the adopted centerline for runways and road __________.

Set 6. Establishing Runway Grade Line by Profile Method

(fill) (5-41)

FRAME 5-42.

It is evident, when a field reconnaissance is made, that certain areas will need to be excavated and certain other areas will need to be filled. These are areas which may be worked on immediately. Areas of cut and fill readily apparent should be __________ on __________.

(1) not (2) stripping (5-71)

FRAME 5-72.

Similarly, in obtaining the volume of embankment shown in column 7, the stripping volume is added to the quantity of embankment shown in column 3, because this much additional material must be used to make the fill. Embankment volume (column 3) plus ________________ volume (column 4) gives ________________ embankment volume.

(grade line) (5-101)

FRAME 5-102.

The lateral positions of these points, one on the mass diagram or one on the profile, will coincide exactly if there is only cut or fill at each station. If both cut and fill exist at the same stations, their positions correspond only ________________

100 (tangents) (5-12)

FRAME 5-13.

Besides at 100-foot intervals, cross sections are plotted at any intermediate place when there is a distinct change along the centerline, and where the natural ground profile and the grade line correspond (earthwork changes from cut to fill). An intermediate interval would be at a ________________ change along the centerline and at changes from ____________ to ____________.

(worked) (immediately) (5-42)

FRAME 5-43.

However, it is often necessary to establish a tentative grade line as a guide in properly assigning equipment prior to detailed computation of earthwork quantities. Establishment of a ________________ grade enables work to proceed before ____________________ computation of earthwork quantities are made.

(stripping) (net) (5-72)

FRAME 5-73.

Net excavation, in cubic yards, available for constructing fills is entered in column (1) ____________________. Column 5 (net excavation) for fills equals applicable figure in column 3 (2) ____________________ figure in column 4.

(approximately) (5-102)

FRAME 5-103.

The mass diagram represents the algebraic summation of net yardage from station to station. Thus the maximum ordinate above or below any balance line represents the total ______________ yardage that is to be moved from cut to fill, disregarding the yardage which is balanced within any 100-foot distance that has both cut and fill.

(distinct) (cut) (fill) (5-13)

FRAME 5-14.

Also, a cross section would be plotted at intermediate places between stations when the surface on either side of the centerline is uneven enough to require plotting in order to represent properly the volumes indicated between the station cross sections. Uneven surfaces between station ________________ ________________ are plotted when necessary for greater accuracy.

(tentative) (detailed) (5-43)

FRAME 5-44.

The tentative grade line should not be carried too close to the final grade. The balance of cut and fill will not be upset if care is taken that cuts and fills are not carried too (1) ________________ to the expected final grade line. The (2) ________________ grade line is a guide and space should be left so that the balance of cut and fill are not (3) ________________.

(1) 5 (2) minus (5-73)

FRAME 5-74.

Net excavation in cubic yards, multiplied by the proper shrinkage or swell factor is listed in column 6. Net excavation of 2378 cubic yards with shrinkage factor of .9 would be ______________ cubic yards.

(net) (5-103)

FRAME 5-104.

In some cases, the excess yardage is not that figured between 100-foot stations, since the yardage is sometimes calculated for shorter or longer distances depending on where the cross sections were taken. Thus in the section of mass diagram (panel 5-8), above the balance line DF, the net yardage which is moved from cut to fill (from section DE to EF) is represented by ordinate ED (vertical distance from E to line DF). The ______________ yardage between D and F must be subtotaled from the yardage table panel 5-6.

(cross sections) (5-14)

FRAME 5-15.

Cross sections are plotted on cross section paper. The subgrade elevation of the finished section at each station is read from the profile. Cross section levels are taken from an instrument in the field, if time permits, or from a contour map. The ________________ elevation of the finished section is read from the profile; cross section levels are taken by ________________ if possible or from a ________________ map.

---

(1) close (2) tentative (3) upset (5-44)

FRAME 5-45.

One method of establishing the ________________ grade line is to plot the centerline profile and the profiles of the shoulder edges. The tentative subgrade grade line is then plotted on the profile bearing in mind minimum earthwork and efficient haul limits.

(2140) (5-74)

FRAME 5-75.

Now let us discuss shrinkage and swell. When placed in a fill and compacted, excavated earth normally will occupy less space than it did before being disturbed. This is called ____________________. If time permits, the decrease in volume, or shrinkage, should be determined by tests.

(total) (5-104)

FRAME 5-105.

The net yardage can be taken from the (1) ____________________; total yardage from (2) ____________________.

(subgrade) (instrument) (contour) (5-15)

FRAME 5-16.

Cross sections usually are plotted to the same vertical and horizontal scale, but if the vertical cut or fill is small in comparison with the width, an exaggerated vertical scale may be used without reducing accuracy. In plottting cross section the same vertical and horizontal ______________________ are generally used.

(tentative) (5-45)

FRAME 5-46.

The centerline (1) ______________________ is first plotted and then the tentative subgrade grade line is plotted on the centerline profile. Minimum (2) ______________________ and efficient (3) ______________________ are kept in mind when plotting the tentative subgrade.

(shrinkage) (5-75)

FRAME 5-76.

If tests cannot be made, the table in panel 5-7 can be used as a guide. It will be noted that in-place sand has a volume of change of ________ when changed to a loose condition.

---

(1) mass diagram (2) yardage table (5-105)

FRAME 5-106.

Total yardage cannot be scaled from the mass diagram unless all the cross sections involved show only cut or fill at any section, which is unlikely. ______ yardage cannot generally be scaled from the mass diagram.

(scales) (5-16)

FRAME 5-17.

After the cross sections are plotted, the area can be calculated by several methods. Two simple methods are **counting the squares** and **triangle method.** ____________ ____________ ____________ method will be discussed first.

---

(1) profile (2) earthwork (3) haul (5-46)

FRAME 5-47.

The grade line corrected for transverse slope is then plotted on the corresponding runway and shoulder edges. The areas between the grade line and the ____________ are then obtained.

(1.11) (5-76)

FRAME 5-77.

After blasting, rock increases in volume. This increase or ____________ occurs because the work fragments do not fit closely together and many voids result.

(Total) (5-106)

FRAME 5-107.

If the balance points do not fall on even stations, proper interpolation must be made in the yardage table. Similarly, the net yardage between points F and G, and G and H is represented by the ordinate ____________________ (the difference between the balance line FH and point G, or 10,000 - 6800 = 3200 cu yd).

("counting the squares") (5-17)

FRAME 5-18.

"Counting the squares" consists of counting the enclosed squares and multiplying the result by the area in square feet of one square. This gives the area of the cross section in square feet. The area in square feet of one square is determined by the horizontal and vertical scales used in plotting the cross section. The number of squares is first counted and this number is multiplied by the area in square feet of ______________ ______________.

(profile) (5-47)

FRAME 5-48.

Cuts should roughly balance fills. The sum of the areas above the grade line (corrected by shrinkage or expansion factor) is ______________ against the sum of the areas below the grade line.

(swell) (5-77)

FRAME 5-78.

One hundred cubic yards of solid rock make 125 to 140 cubic yards of embankment, depending on the type of rock, the amount and type of explosive used, and the size to which it is crushed. The increase from 100 cubic yards to ________________- 140 cubic yards of rock is called ________________.

(FG) (5-107)

FRAME 5-108.

The mass diagram (panel 5-8) also shows the net quantity to be borrowed or wasted. Remembering that the lines BJ and KM represent an efficient haul distance of 1,000 feet, the excess material between A and B should be (1) ________________ and the material needed for the embankment between J and K should be (2) ________________ to avoid (3) ________________ haul.

(one square) (5-18)

FRAME 5-19.

In the triangle method, area is obtained by **subdividing** the cross section into a series of **triangles**. Geometrically, the area of a triangle is ½ the product of the base times its height ($A=bh/2$). Therefore, the cross section area can be obtained by adding the individual products of base times height for all the ______________ into which the cross section is ______________ and dividing the sum by ______________.

(balanced) (5-48)

FRAME 5-49.

The tentative grade line is shifted until the areas obtained are roughly in (1) ______________. The balancing of cut and fill require the (2) ______________ of the tentative grade line.

125 (swell) (5-78)

FRAME 5-79.

If the fill is composed entirely of rock, the full ________________ factor for the type of rock being quarried is used.

---

(1) wasted (2) borrowed (3) excessive (5-108)

FRAME 5-109.

The 1,000-foot distance used in this example and the resulting borrow and waste are for illustrative purposes only. Actually it will frequently be more economical to haul material several thousand feet than to ________________ and ________________.

(triangles) (subdivided) (2) (5-19)

FRAME 5-20.

Bases of the triangles are taken as the vertical distances between the ground and grade lines where the slope of either line (or both) changes. The length of each triangle base is equal to the elevation difference in feet, between ground and grade lines. The altitude of each triangle is taken as the horizontal distance, in feet, between the cross section points at the base and the apex of the triangle. Bases of triangles are vertical distances between the ________________ and ____________ lines where the slope of either one or both changes.

Set 7. Computing Borrow Pit Volumes

(1) balance (2) shifting (5-49)

FRAME 5-50.

There are two methods of computing the volume of material excavated (or to be excavated) from a borrow pit. One method is to take original and final cross sections at right angles to a convenient baseline, determine the cross section ________________________, and then determine the ________________________.

(swell) (5-79)

FRAME 5-80.

If the rock is placed simultaneously with earth fill and all interstices or voids are carefully filled and compacted, rock swell will roughly equal earth shrinkage, so both factors may be practically ______________.

(waste) (borrow) (5-109)

FRAME 5-110.

Where there is either waste or borrow, the mass diagram shows the quantity, but not the length and direction of haul. One method of obtaining these is to make a sketch map showing borrow or waste area and the approximate center of mass of the quantities involved. The mass diagram shows the ______ ______________ of either waste or borrow.

(ground) (grade) (5-20)

FRAME 5-21.

The altitude of each triangle is taken as the horizontal distance between the cross section points at the ______________ and the ______________ of the triangle.

---

(1) areas (2) volume (5-50)

FRAME 5-51.

The other method (panel 5-5) is to divide a plan view of the pit into a system of squares or rectangles, usually 20 to 50 feet on a side depending on the roughness of surface. The plan view of the pit is first divided into a system of ______________ or ______________.

(disregarded) (5-80)

FRAME 5-81.

The shrinkage or swell factor is applied to excavation quantities so that the position of the excavation in the embankment will not affect the plotting of the mass diagram. The excavation quantity is found in column ________________ of the Earthwork and Mass Diagram (panel 5-6) computation sheet.

(quantity) (5-110)

FRAME 5-111.

The difference in length between any two ordinates is a measure of the total net yardage of excess or deficiency of material between the stations at which the ordinates are drawn. The difference in length between two ordinates will give the amount of net excess or ____________________ between the stations at which the ordinates are drawn.

(base) (apex) (5-21)

FRAME 5-22.

Thus far each triangle in the series of triangles into which the cross section may be divided has been considered individually. The triangle method, however, goes one step further (panel 5-2). Here it can be seen that the cross section area is more easily computed if two triangles with a common base are considered together. The triangle method considers ________ ________ with a ________ ________ as one.

(squares) (rectangles) (5-51)

FRAME 5-52.

Next, the difference in elevation of the original ground and the grade of the excavation at the corners of the squares or rectangles is determined and plotted along the plan view. This results in a series of prisms (panel 5-5) from which cross section ________ can be computed.

3 (5-81)

FRAME 5-82.

The swell or (1) ________________ factor may not be constant throughout the project. If so, each factor value should be used for the section to which it (2) ________________.

(deficiency) (5-111)

FRAME 5-112.

Where the mass line ends above the zero ordinate line, there is an excess of excavation to be (1) ________________. If the mass line ends below the zero ordinate line, there is a deficiency of of excavation which must be (2) ________________.

(two) (triangles) (common) (base) (5-22)

FRAME 5-23.

In the triangle method, the altitudes of two triangles are added and then multiplied by the length of their common base. Therefore, the cross section area can be obtained by adding the products of all the pairs having a common base. As before, the sum of all these products is divided by 2 to obtain the true total area. In the triangle method, two triangles with a ________________ ________________ can be combined and thus cuts the required computations in half.

(areas) (5-52)

FRAME 5-53.

The volume of each prism is determined and then these volumes are ________ ________________ to get the total area of the pit.

(1) shrinkage (2) applies (5-82)

FRAME 5-83.

Frames 5-83 through 5-89 pertain to panel 5-6. Total material in cubic yards required to construct fills is entered in column ________________.

---

(1) wasted (2) borrowed (5-112)

FRAME 5-113.

Generally, the average length of haul is approximately equal to the length of a horizontal line drawn midway between the peak of the mass line and the balance line. Line CI (panel 5-8) represents the approximate average length of haul for placing the excavation BD in the embankment (1) ________________. Similarly, line NN′ represents the approximate (2) ________________ of haul for placing the excavation in the embankment (3) ________________.

(common) (base) (5-23)

FRAME 5-24.

Working from left to right the area of the cross section is obtained as in panel 5-2. Completing the computations in panel 5-2 the area of the cross section is found to be ________________ square feet.

(totaled or added) (5-53)

FRAME 5-54.

When the depth of excavation is uniform throughout the pit, the computation of this second method can be expressed in one formula. Referring to panel 5-5, the formula for the borrow pit in cubic yards is:

$$\frac{(n \times dab) + \left(m \times \frac{dab}{2}\right)}{27}$$

where d = average height (depth of excavation)

a, b = length of sides in feet

n = number of squares or rectangles

m = number of triangles

Depth of excavation must be ________________ to use the ________________ for volume computations.

7 (5-83)

FRAME 5-84.

The quantity given in column 7 is the sum of embankment quantities given in columns __________ and __________.

Set 10. Selection of Equipment by Use of Mass Diagram

(1) HJ (2) average length (3) KL (5-113)

FRAME 5-114.

In order to explain further the use of the mass diagram in analyzing and planning earthwork operations, consider the portion of the mass diagram from K to M (panel 5-8). Excavation from LM will be placed in embankment __________
__________.

Set 4. Average-End-Area Method

191.1 (5-24)

FRAME 5-25.

The average-end-area method is the method most commonly used to determine the volume between two cross sections or end areas. Use is made of the following formula:

$$V = \frac{L\ (A_1 + A_2)}{54}$$

Where:

V = volume in cubic yards of the prismoid between areas A_1 and A_2

L = distance in feet between end areas A_1 and A_2 = end areas in square feet

In the average-end-area formula L = (1) ____________ in (2) ____________ between (3) ____________ areas, and $A_1 + A_2$ = area of (4) ____________ sections in square feet.

Set 8. Mass Diagram

(uniform) (formula) (5-54)

FRAME 5-55.

The mass diagram is the best means of making a study of the excess volumes of earthwork between stations on an earthmoving project. It does not take into account balanced yardage between stations. The mass diagram is a means of studying ______________ ______________ of earthwork between stations.

(3) (4) (5-84)

FRAME 5-85.

Balanced yardage, in cubic yards, between stations is entered in column 8. This is the yardage cancelled out in obtaining the algebraic sum. The yardage cancelled out for station 28 + 00 is ________________.

(KL) (5-114)

FRAME 5-115.

The direction of haul will be from right to left. This is because this is a ________________ hump.

(1) distance (2) feet (3) end (4) cross (or end) (5-25)

FRAME 5-26.

If cross sections are taken at full 100-foot stations the volume in cubic yards between successive square foot cross sections (A_1 and A_2) may be found directly by the formula

$$V = 1.85 (A_1 + A_2)$$

The above formula may be used when the cross sections are taken at full ____________________ foot stations.

(excess) (volumes) (5-55)

FRAME 5-56.

The ____________________ ____________________ aids in determining the quickest way to complete an earthmoving job and also serves as a guide in determining what equipment to assign to specific portions of the haul.

(93) (5-85)

FRAME 5-86.

The balanced yardage for station 29 + 00 is ________________. The balanced yardage figure is used only for the purposes of estimating construction time and the scheduling of men and equipment.

(sag) (5-115)

FRAME 5-116.

The average length of haul is represented by the line NN′ which is approximately 420 feet. The best equipment for this ______________ of ______________ is a wheeled tractor scraper combination.

(100) (5-26)

FRAME 5-27.

In either form, the formula is entirely accurate only when A_1 and A_2 are approximately of the same shape. The (1) ________________ areas must be of approximately the same shape for the formula in either form to be entirely (2) ________________. The greater the difference in (3) ________________ between the two end areas, the greater the error.

(mass diagram) (5-56)

FRAME 5-57.

The mass diagram serves as a guide in determining what ________________ to assign specific ________________ ________________.

(327) (5-86)

FRAME 5-87.

The algebraic sum for station 28 + 00 is obtained by adding net embankment amount and factored (1) ________________. From this we see that in obtaining the algebraic sum, the excavation is considered plus the embankment is (2) ________________.

(length) (haul) (5-116)

FRAME 5-117.

In order to estimate time, equipment, and personnel requirements, it is necessary to know the volume of earthwork between K and M. This is done in two ways — either by selection from the computation sheet, or where applicable, scaling off the volume from ordinates of the mass diagram. The latter method is of sufficient accuracy for most situations. The ________________ sheet is used for greater accuracy; the ________________ method is suitable for most jobs.

(1) end (2) accurate (3) shape (5-27)

FRAME 5-28.

Even though an error as great as 50% can occur and the results obtained are approximate, this method is consistent with other field computations and more accuracy is not justified. This method is of sufficient ______________ for use in estimating earthwork volumes.

(equipment) (haul) (portions) (5-57)

FRAME 5-58.

The mass diagram is a graph on which the algebraic sum of the embankment and corrected excavation is plotted against linear distance. The mass diagram is a graph with two variables: Algebraic sum of the embankment and corrected excavation and ______________ ______________.

(excavation) (minus) (5-87)

FRAME 5-88.

The ordinate or cumulative total of the items in column 9 is placed in column ________________, with the proper algebraic sign.

(computation) (scaling) (5-117)

FRAME 5-118.

If the computation sheet is used in combination with the mass diagram, the procedure below is followed. Since K does not fall at an even station, it is necessary to determine this point and compute additional values to be inserted in the computation sheet (panel 5-6). This is done by straight-line arithmetic interpolation. Points not falling at an even station are computed by straight-line ________________ ________________ and are inserted in the computation sheet.

(accuracy) (5-28)

FRAME 5-29.

Volumes by average end areas may be obtained directly from an earthwork table. Note that the table (panel 5-3) is to be used with the sum of end areas and that it is not necessary to calculate the average end areas. A table can be used which requires only the ________________ of the end areas to find the volume.

(linear distance) (5-58)

FRAME 5-59.

The algebraic sum of the embankment and the excavation is plotted as the ordinate, and the linear distance as the abcissa. The algebraic sum of the embankment and the excavation is plotted as the ________________.

(10) (5-88)

FRAME 5-89.

For ease in comparison, the horizontal scale for the mass diagram and the centerline profile should be the same — and one placed directly above the other as shown in panel 5-8. The vertical scale for mass diagram may be any convenient one — such as 1,000, 5,000, or 10,000 cubic yards per inch. The vertical scale for the centerline profile should be normally plotted ground elevations in feet. The horizontal scales of the mass diagram and the centerline profile are the _______________.

(arithmetic) (interpolation) (5-118)

FRAME 5-119.

Point K (panel 5-8) is found to be at station 44 + 92. The following values are computed and inserted in the yardage table: the numbers for station 46 + 00 replace those shown in the tabulation panel 5-6.

(1)	(6)	(7)	(8)	(9)	(10)
44 + 92	355	1213	355	–858	–746
46 + 00	1659	5767	1659	–4108	–3362

The above numbers are the corrections to be made in respective columns of the _______________ sheet.

(sum) (5-29)

FRAME 5-30.

Following is an example of the use of the earthwork table in Panel 5-3. Two cross sections 100 feet apart have areas of 100.1 and 300.2 square feet respectively. The sum of the areas is 400.3 square feet. The figure 400 is found to the left of the heavy line under the column headed ________________. On the same line with 400 and under the column 0.3 (to the right of the heavy line) is found the figure ________________.

Turn back to bottom of of page 5-3.

(ordinate) (5-59)

FRAME 5-60.

The algebraic sums are obtained by using excavation quantities as positive and embankment quantities as negative. Positive values are ________________ quantities; negative values are ________________ quantities.

Turn back to top of page 5-4.

(same) (5-89)

FRAME 5-90.

The vertical scale of the centerline profile consists of the ________________ in feet, and the vertical scale of the mass diagram consists of any ________________ one in cubic yards per inch.

Turn back to bottom of page 5-4.

(computation) (5-119)

FRAME 5-120.

Having established the numbers for stations 46 + 00, to find the value of earthwork between stations K and M proceed as in panel 5-9. The final quantity (________________ cu yds) is the volume which must be used in determining equipment and personnel requirements and in establishing construction schedules.

(21,460) (5-120)

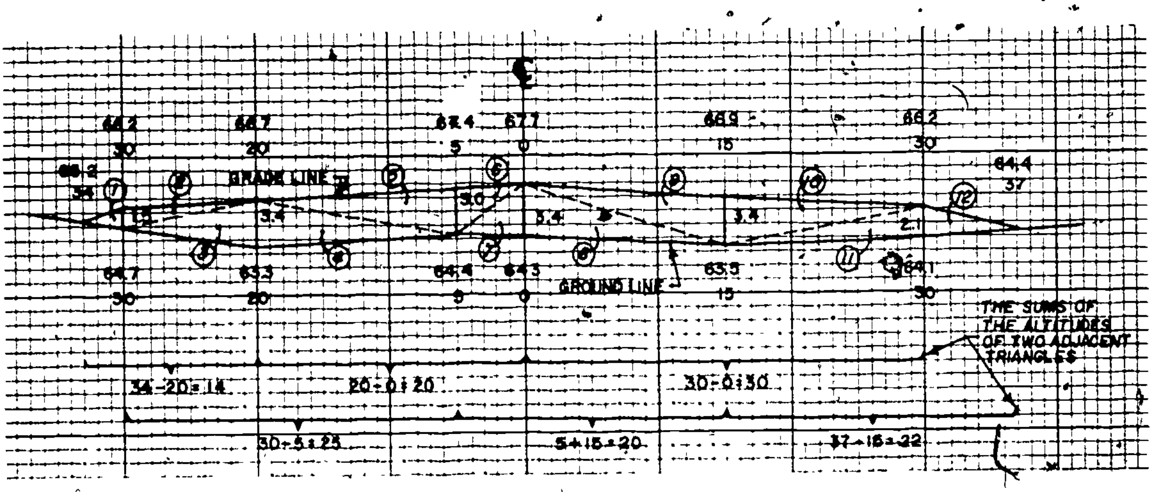
END OF FRAMES

PANELS AND SELF TEST FOLLOW

Panel 5-1. Volume of Cuts and Fills in Cubic Yards per 100 feet of Length (for Level Sections).

1	2	3	4	5	6	7	8	9	10	11	12
Average depth of cut or height of fill (feet)	Side slope 1 to 1—width of base of cut or crown of fill (feet)								Add for each additional 2 feet of width	Add where slope is 1 ½ to 1	Add where slope is 2 to 1
	14	16	18	20	24	28	30	42			
1	56	63	70	78	92	107	115	159	7	2	4
2	119	133	148	163	192	222	237	326	15	7	15
3	189	211	233	256	300	344	367	500	22	16	33
4	267	296	326	356	415	474	504	682	30	30	59
5	352	389	426	463	537	611	648	870	37	46	93
6	444	489	533	578	667	756	800	1,065	45	67	133
7	544	596	648	700	803	907	959	1,271	52	91	181
8	652	711	770	830	948	1,067	1,126	1,483	59	118	237
9	767	833	900	967	1,100	1,233	1,300	1,700	67	150	300
10	889	936	1,037	1,111	1,259	1,407	1,481	1,928	74	185	370
11	1,019	1,100	1,181	1,263	1,426	1,589	1,670	2,159	82	224	448
12	1,156	1,244	1,338	1,422	1,600	1,778	1,867	2,400	89	267	534
13	1,300	1,396	1,493	1,589	1,781	1,974	2,070	2,649	96	313	626
14	1,452	1,556	1,659	1,763	1,970	2,178	2,281	2,904	104	363	725
15	1,611	1,722	1,833	1,944	2,166	2,389	2,500	3,167	111	426	852
16	1,778	1,896	2,015	2,133	2,370	2,607	2,726	3,437	119	474	948
17	1,952	2,078	2,204	2,330	2,581	2,833	2,959	3,715	126	534	1,068
18	2,133	2,267	2,400	2,533	2,800	3,067	3,200	4,000	133	598	1,196
19	2,322	2,463	2,604	2,744	3,025	3,307	3,448	4,293	141	667	1,334
20	2,519	2,667	2,815	2,963	3,259	3,556	3,704	4,593	148	740	1,480
21	2,722	2,878	3,033	3,189	3,500	3,811	3,967	4,900	156	815	1,630
22	2,933	3,096	3,259	3,422	3,748	4,074	4,237	5,215	163	894	1,788

Panel 5-2. Triangle Method of Determining Cross Section Areas.



Remember (frame 5—23):

The sums of the altitudes of two adjacent triangles are taken as the horizontal distance in feet between the cross section points adjacent to their common base. (See above cross section)

The common base is taken as the vertical distance between the ground line and grade line at the point of change between the two adjacent triangles.

Working from left to right, the area of the cross section is obtained as follows:

Base × Total Altitude = 2 × Area of the Two Triangles

Triangles 1 & 2 = 1.5 × (34 — 20) = 1.5 × 14 = 21.0

3 & 4 = 3.4 × (30 — 5) = 3.4 × 25 = 85.0

etc. 3.0 × (20 — 0) =

3.4 × (5 + 15) =

3.4 × (30 — 0) =

2.1 × (37 — 15) = ________

Total ________ /2 = ________ ft²

Don't forget to divide area obtained by 2 (frame 5-19)

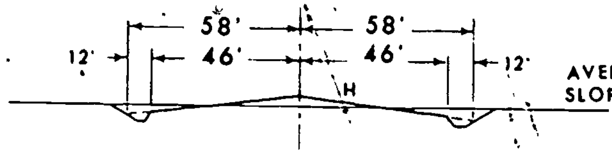
Panel 5-3. Cubic Yards in 100-foot Prisms with Specified Sums of End Areas.

3,000	2,900	2,800	2,700	2,600	2,500	2,400	2,300	2,200	2,100	2,000	1,900	1,800	1,700	1,600	1,500	1,400	1,300	1,200	1,100	1,000
1,620	1,566	1,512	1,458	1,404	1,350	1,296	1,242	1,188	1,134	1,080	1,026	972	918	864	810	756	702	648	594	540
1,621	1,567	1,513	1,459	1,405	1,351	1,297	1,243	1,189	1,135	1,081	1,027	973	919	865	811	757	703	649	595	541
1,622	1,568	1,514	1,460	1,406	1,352	1,298	1,244	1,190	1,136	1,082	1,028	974	920	866	812	758	704	650	596	542
1,623	1,569	1,515	1,461	1,407	1,353	1,299	1,245	1,191	1,137	1,083	1,029	975	921	867	813	759	705	651	597	543
1,624	1,570	1,516	1,462	1,408	1,354	1,300	1,246	1,192	1,138	1,084	1,030	976	922	868	814	760	706	652	598	544
1,625	1,571	1,517	1,463	1,409	1,355	1,301	1,247	1,193	1,139	1,085	1,031	977	923	869	815	761	707	653	599	545
1,626	1,572	1,518	1,464	1,410	1,356	1,302	1,248	1,194	1,140	1,086	1,032	978	924	870	816	762	708	654	600	546
1,627	1,573	1,519	1,465	1,411	1,357	1,303	1,249	1,195	1,141	1,087	1,033	979	925	871	817	763	709	655	601	547
1,628	1,574	1,520	1,466	1,412	1,358	1,304	1,250	1,196	1,142	1,088	1,034	980	926	872	818	764	710	656	602	548
1,629	1,575	1,521	1,467	1,413	1,359	1,305	1,251	1,197	1,143	1,089	1,035	981	927	873	819	765	711	657	603	549
1,630	1,576	1,522	1,468	1,414	1,360	1,306	1,252	1,198	1,144	1,090	1,036	982	928	874	820	766	712	658	604	550
1,631	1,577	1,523	1,469	1,415	1,361	1,307	1,253	1,199	1,145	1,091	1,037	983	929	875	821	767	713	659	605	551
1,632	1,578	1,524	1,470	1,416	1,362	1,308	1,254	1,200	1,146	1,092	1,038	984	930	876	822	768	714	660	606	552
1,633	1,579	1,525	1,471	1,417	1,363	1,309	1,255	1,201	1,137	1,093	1,039	985	931	877	823	769	715	661	607	553
1,634	1,580	1,526	1,472	1,418	1,364	1,310	1,256	1,202	1,148	1,094	1,040	986	932	878	824	770	716	662	608	554
1,635	1,581	1,527	1,473	1,419	1,365	1,311	1,257	1,203	1,149	1,095	1,041	987	933	879	825	771	717	663	609	555
1,636	1,582	1,528	1,474	1,420	1,366	1,312	1,258	1,204	1,150	1,096	1,042	988	934	880	826	772	718	664	610	556
1,637	1,583	1,529	1,475	1,421	1,367	1,313	1,259	1,205	1,151	1,097	1,043	989	935	881	827	773	719	665	611	557
1,638	1,584	1,530	1,476	1,422	1,368	1,314	1,260	1,206	1,152	1,098	1,044	990	936	882	828	774	720	666	612	558
1,639	1,585	1,531	1,477	1,423	1,369	1,315	1,261	1,207	1,153	1,099	1,045	991	937	883	829	775	721	667	613	559
1,640	1,586	1,532	1,478	1,424	1,370	1,316	1,262	1,208	1,154	1,100	1,046	992	938	884	830	776	722	668	614	560
1,641	1,587	1,533	1,479	1,425	1,371	1,317	1,263	1,209	1,155	1,101	1,047	993	939	885	831	777	723	669	615	561
1,642	1,588	1,534	1,480	1,426	1,372	1,318	1,264	1,210	1,156	1,102	1,048	994	940	886	832	778	724	670	616	562
1,643	1,589	1,535	1,481	1,427	1,373	1,319	1,265	1,211	1,157	1,103	1,049	995	941	887	833	779	725	671	617	563
1,644	1,590	1,536	1,482	1,428	1,374	1,320	1,266	1,212	1,158	1,104	1,050	996	942	888	834	780	726	672	618	564
1,645	1,591	1,537	1,483	1,429	1,375	1,321	1,267	1,213	1,159	1,105	1,051	997	943	889	835	781	727	673	619	565
1,646	1,592	1,538	1,484	1,430	1,376	1,322	1,268	1,214	1,160	1,106	1,052	998	944	890	836	782	728	674	620	566
1,647	1,593	1,539	1,485	1,431	1,377	1,323	1,269	1,215	1,161	1,107	1,053	999	945	891	837	783	729	675	621	567
1,648	1,594	1,540	1,486	1,432	1,378	1,324	1,270	1,216	1,162	1,108	1,054	1,000	946	892	838	784	730	676	622	568
1,649	1,595	1,541	1,487	1,433	1,379	1,325	1,271	1,217	1,163	1,109	1,055	1,001	947	893	839	785	731	677	623	569
1,650	1,596	1,542	1,488	1,434	1,380	1,326	1,272	1,218	1,164	1,110	1,056	1,002	948	894	840	786	732	678	624	570
1,651	1,597	1,543	1,489	1,435	1,381	1,327	1,273	1,219	1,165	1,111	1,057	1,003	949	895	841	787	733	679	625	571
1,652	1,598	1,544	1,490	1,436	1,382	1,328	1,274	1,220	1,166	1,112	1,058	1,004	950	896	842	788	734	680	626	572
1,653	1,599	1,545	1,491	1,437	1,383	1,329	1,275	1,221	1,167	1,113	1,059	1,005	951	897	843	789	735	681	627	573
1,654	1,600	1,546	1,492	1,438	1,384	1,330	1,276	1,222	1,168	1,114	1,060	1,006	952	898	844	790	736	682	628	574
1,655	1,601	1,547	1,493	1,439	1,385	1,331	1,277	1,223	1,169	1,115	1,061	1,007	953	899	845	791	737	683	629	575
1,656	1,602	1,548	1,494	1,440	1,386	1,332	1,278	1,224	1,170	1,116	1,062	1,008	954	900	846	792	738	684	630	576
1,657	1,603	1,549	1,495	1,441	1,387	1,333	1,279	1,225	1,171	1,117	1,063	1,009	955	901	847	793	739	685	631	577
1,658	1,604	1,550	1,496	1,442	1,388	1,334	1,280	1,226	1,172	1,118	1,064	1,010	956	902	848	794	740	686	632	578
1,659	1,605	1,551	1,497	1,443	1,389	1,335	1,281	1,227	1,173	1,119	1,065	1,011	957	903	849	795	741	687	633	579
1,660	1,606	1,552	1,498	1,444	1,390	1,336	1,282	1,228	1,174	1,120	1,066	1,012	958	904	850	796	742	688	634	580
1,661	1,607	1,553	1,499	1,445	1,391	1,337	1,283	1,229	1,175	1,121	1,067	1,013	959	905	851	797	743	689	635	581
1,662	1,608	1,554	1,500	1,446	1,392	1,338	1,284	1,230	1,176	1,122	1,068	1,014	960	906	852	798	744	690	636	582
1,663	1,609	1,555	1,501	1,447	1,393	1,339	1,285	1,231	1,177	1,123	1,069	1,015	961	907	853	799	745	691	637	583
1,664	1,610	1,556	1,502	1,448	1,394	1,340	1,286	1,232	1,178	1,124	1,070	1,016	962	908	854	800	746	692	638	584
1,665	1,611	1,557	1,503	1,449	1,395	1,341	1,287	1,233	1,179	1,125	1,071	1,017	963	909	855	801	747	693	639	585
1,666	1,612	1,558	1,504	1,450	1,396	1,342	1,288	1,234	1,180	1,126	1,072	1,018	964	910	856	802	748	694	640	586
1,667	1,613	1,559	1,505	1,451	1,397	1,343	1,289	1,235	1,181	1,127	1,073	1,019	965	911	857	803	749	695	641	587
1,668	1,614	1,560	1,506	1,452	1,398	1,344	1,290	1,236	1,182	1,128	1,074	1,020	966	912	858	804	750	696	642	588
1,669	1,615	1,561	1,507	1,453	1,399	1,345	1,291	1,237	1,183	1,129	1,075	1,021	967	913	859	805	751	697	643	589
1,670	1,616	1,562	1,508	1,454	1,400	1,346	1,292	1,238	1,184	1,130	1,076	1,022	968	914	860	806	752	698	644	590
1,671	1,617	1,563	1,509	1,455	1,401	1,347	1,293	1,238	1,185	1,131	1,077	1,023	969	915	861	807	753	699	645	591
1,672	1,618	1,564	1,510	1,456	1,402	1,348	1,294	1,240	1,186	1,132	1,078	1,024	970	916	862	808	754	700	646	592
1,673	1,619	1,565	1,511	1,457	1,403	1,349	1,295	1,241	1,187	1,133	1,079	1,025	971	917	863	809	755	701	647	593

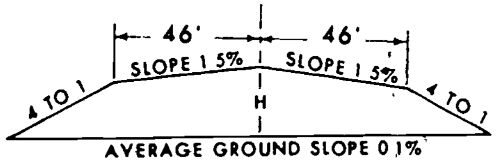
Panel 5-3. Continued.

900	800	700	600	500	400	300	200	100	0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
486	432	378	324	270	216	162	108	54	0	0.00	0.18	0.37	0.56	0.74	0.93	1.11	1.30	1.48	1.67
487	433	379	325	271	217	163	109	55	1	1.85	2.04	2.22	2.41	2.59	2.78	2.96	3.15	3.33	3.52
488	434	380	326	272	218	164	110	56	2	3.70	3.89	4.07	4.26	4.44	4.63	4.82	5.00	5.18	5.37
489	435	381	327	273	219	165	111	57	3	5.56	5.74	5.93	6.11	6.30	6.48	6.67	6.85	7.04	7.22
490	436	382	328	274	220	166	112	58	4	7.41	7.59	7.78	7.96	8.15	8.33	8.52	8.70	8.89	9.07
491	437	383	329	275	221	167	113	59	5	9.26	9.44	9.63	9.81	10.00	10.19	10.37	10.56	10.74	10.93
492	438	384	330	276	222	168	114	60	6	11.11	11.30	11.48	11.67	11.85	12.04	12.22	12.41	12.59	12.78
493	439	385	331	277	223	169	115	61	7	12.96	13.15	13.33	13.52	13.70	13.89	14.07	14.26	14.44	14.63
494	440	386	332	278	224	170	116	62	8	14.82	15.00	15.19	15.37	15.56	15.74	15.93	16.11	16.30	16.48
495	441	387	333	279	225	171	117	63	9	16.67	16.85	17.04	17.22	17.41	17.59	17.78	17.96	18.15	18.33
496	442	388	334	280	226	172	118	64	10	18.52	18.70	18.89	19.07	19.26	19.44	19.63	19.82	20.00	20.18
497	443	389	335	281	227	173	119	65	11	20.37	20.56	20.74	20.93	21.11	21.30	21.48	21.67	21.85	22.04
498	444	390	336	282	228	174	120	66	12	22.22	22.41	22.59	22.78	22.96	23.15	23.33	23.52	23.70	23.89
499	445	391	337	283	229	175	121	67	13	24.07	24.26	24.44	24.63	24.82	25.00	25.18	25.37	25.56	25.74
500	446	392	338	284	230	176	122	68	14	25.93	26.11	26.30	26.48	26.67	26.85	27.04	27.22	27.41	27.59
501	447	393	339	285	231	177	123	69	15	27.78	27.96	28.15	28.33	28.52	28.70	28.89	29.07	29.26	29.44
502	448	394	340	286	232	178	124	70	16	29.63	29.82	30.00	30.18	30.37	30.56	30.74	30.93	31.11	31.30
503	449	395	341	287	233	179	125	71	17	31.48	31.67	31.85	32.04	32.22	32.41	32.59	32.78	32.96	33.15
504	450	396	342	288	234	180	126	72	18	33.33	33.52	33.70	33.89	34.07	34.26	34.44	34.63	34.82	35.00
505	451	397	343	289	235	181	127	73	19	35.18	35.37	35.56	35.74	35.93	36.11	36.30	36.48	36.67	36.85
506	452	398	344	290	236	182	128	74	20	37.04	37.22	37.41	37.59	37.78	37.96	38.15	38.33	38.52	38.70
507	453	399	345	291	237	183	129	75	21	38.89	39.07	39.26	39.44	39.63	39.82	40.00	40.19	40.37	40.56
508	454	400	346	292	238	184	130	76	22	40.74	40.93	41.11	41.30	41.48	41.67	41.85	42.04	42.22	42.41
509	455	401	347	293	239	185	131	77	23	42.59	42.78	42.96	43.15	43.33	43.52	43.70	43.89	44.07	44.26
510	456	402	348	294	240	186	132	78	24	44.44	44.63	44.81	45.00	45.19	45.37	45.56	45.74	45.93	46.11
511	457	403	349	295	241	187	133	79	25	46.30	46.48	46.67	46.85	47.04	47.22	47.41	47.59	47.78	47.96
512	458	404	350	296	242	188	134	80	26	48.15	48.33	48.52	48.70	48.89	49.07	49.26	49.44	49.63	49.82
513	459	405	351	297	243	189	135	81	27	50.00	50.19	50.37	50.56	50.74	50.93	51.11	51.30	51.48	51.67
514	460	406	352	298	244	190	136	82	28	51.84	52.04	52.22	52.41	52.59	52.78	52.96	53.15	53.33	53.52
515	461	407	353	299	245	191	137	83	29	53.70	53.89	54.07	54.26	54.44	54.63	54.81	55.00	55.46	55.37
516	462	408	354	300	246	192	138	84	30	55.56	55.74	55.93	56.11	56.30	56.48	56.67	56.85	57.04	57.22
517	463	409	355	301	247	193	139	85	31	57.41	57.59	57.78	57.96	58.15	58.33	58.52	58.70	58.89	59.07
518	464	410	356	302	248	194	140	86	32	59.26	59.44	59.63	59.82	60.00	60.18	60.37	60.56	60.74	60.93
519	465	411	357	303	249	195	141	87	33	61.11	61.30	61.48	61.67	61.85	62.04	62.22	62.41	62.59	62.78
520	466	412	358	304	250	196	142	88	34	62.96	63.15	63.33	63.52	63.70	63.89	64.07	64.26	64.44	64.63
521	467	413	359	305	251	197	143	89	35	64.82	65.00	65.18	65.37	65.56	65.74	65.93	66.11	66.30	66.48
522	468	414	360	306	252	198	144	90	36	66.67	66.85	67.04	67.22	67.41	67.59	67.78	67.96	68.15	68.33
523	469	415	361	307	253	199	145	91	37	68.52	68.70	68.89	69.07	69.26	69.44	69.63	69.82	70.00	70.18
524	470	416	362	308	254	200	146	92	38	70.37	70.56	70.74	70.93	71.11	71.30	71.48	71.67	71.85	72.04
525	471	417	363	309	255	201	147	93	39	72.22	72.41	72.59	72.78	72.96	73.15	73.33	73.52	73.70	73.89
526	472	418	364	310	256	202	148	94	40	74.07	74.26	74.44	74.63	74.82	75.00	75.18	75.37	75.56	75.74
527	473	419	365	311	257	203	149	95	41	75.93	76.11	76.30	76.48	76.67	76.85	77.04	77.22	77.41	77.59
528	474	420	366	312	258	204	150	96	42	77.78	77.96	78.15	78.33	78.52	78.70	78.89	79.07	79.25	79.44
529	475	421	367	313	259	205	151	97	43	79.63	79.82	80.00	80.18	80.37	80.56	80.74	80.93	81.11	81.30
530	476	422	368	314	260	206	152	98	44	81.48	81.67	81.85	82.04	82.22	82.41	82.59	82.78	82.96	83.15
531	477	423	369	315	261	207	153	99	45	83.33	83.52	83.70	83.89	84.07	84.26	84.44	84.63	84.82	85.00
532	478	424	370	316	262	208	154	100	46	85.19	85.37	85.56	85.74	85.93	86.11	86.30	86.48	86.67	86.85
533	479	425	371	317	263	209	155	101	47	87.04	87.22	87.41	87.59	87.78	87.96	88.15	88.33	88.52	88.70
534	480	426	372	318	264	210	156	102	48	88.89	89.07	89.26	89.44	89.63	89.82	90.00	90.18	90.37	90.56
535	481	427	373	319	265	211	157	103	49	90.74	90.93	91.11	91.30	91.48	91.67	91.85	92.04	92.22	92.41
536	482	428	374	320	266	212	158	104	50	92.59	92.78	92.96	93.15	93.33	93.52	93.70	93.89	94.07	94.26
537	483	429	375	321	267	213	159	105	51	94.44	94.63	94.82	95.00	95.18	95.37	95.56	95.74	95.93	96.11
538	484	430	376	322	268	214	160	106	52	96.30	96.48	96.67	96.85	97.04	97.22	97.41	97.59	97.78	97.96
539	485	431	377	323	269	215	161	107	53	98.15	98.33	98.52	98.70	98.89	99.07	99.26	99.44	99.63	99.82

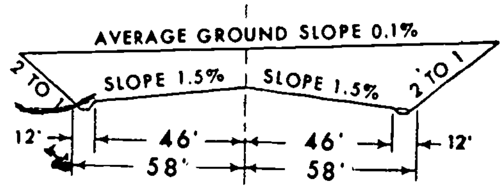
Panel 5-4. Method of Making Quick Preliminary Estimate of Airfield Earthwork.



SECTION WHERE FILL H 3'



FILL SECTION

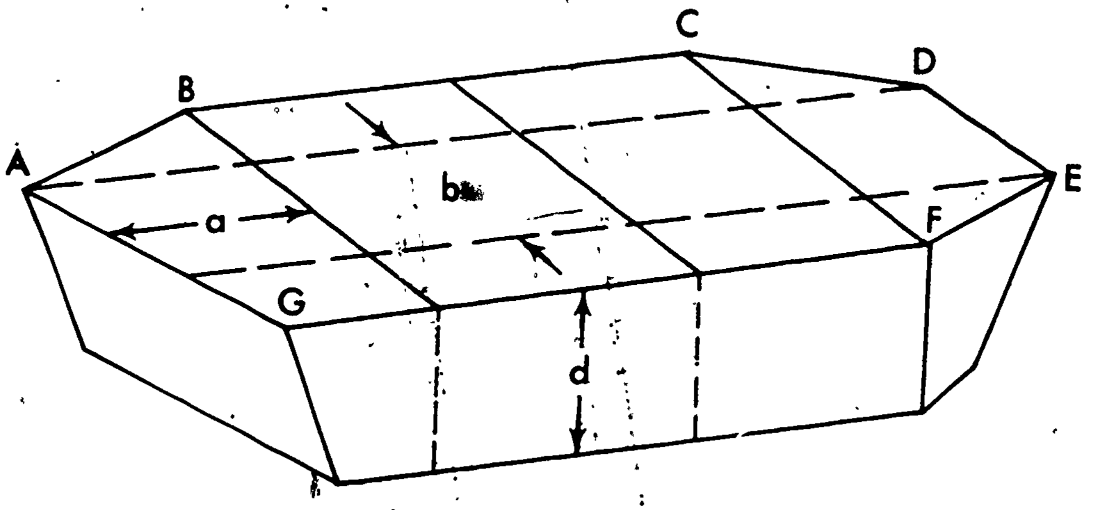


CUT SECTION

AVERAGE DEPTH OF CUT OR HEIGHT OF FILL IN FEET	VOLUMES IN CUBIC YARDS PER 100 FEET OF LENGTH			
DIMENSION H	FILL	CUT	FACTOR CUT TO FILL	CUT TIMES FACTOR
FILL-0	0	500	0.8	400
CUT-0	0	500	0.8	400
FILL-1	85	165	0.8	132
CUT-1		830	0.8	664
FILL-2	295	20		16
CUT-2		1,375	0.8	1,100
FILL-3	700			
CUT-3		1,760	0.85	1,495
FILL-4	1,080			
CUT-4		1,975	0.85	1,680
FILL-5	1,475			
CUT-5		2,350	0.85	2,000

FACTOR OF CUT TO FILL BASED ON 125 CU.YDS. OF EXCAVATION REQUIRED TO MAKE 100 CU.YDS. OF FILL (100/125=0.8) CUT TIMES FACTOR GIVES VOLUME OF FILL THAT CAN BE MADE FROM CUT.

Panel 5-5. Layout for Determining Volume of Borrow Pit.



Panel 5-6. Typical Earthwork and Mass Diagram Computation Sheet.

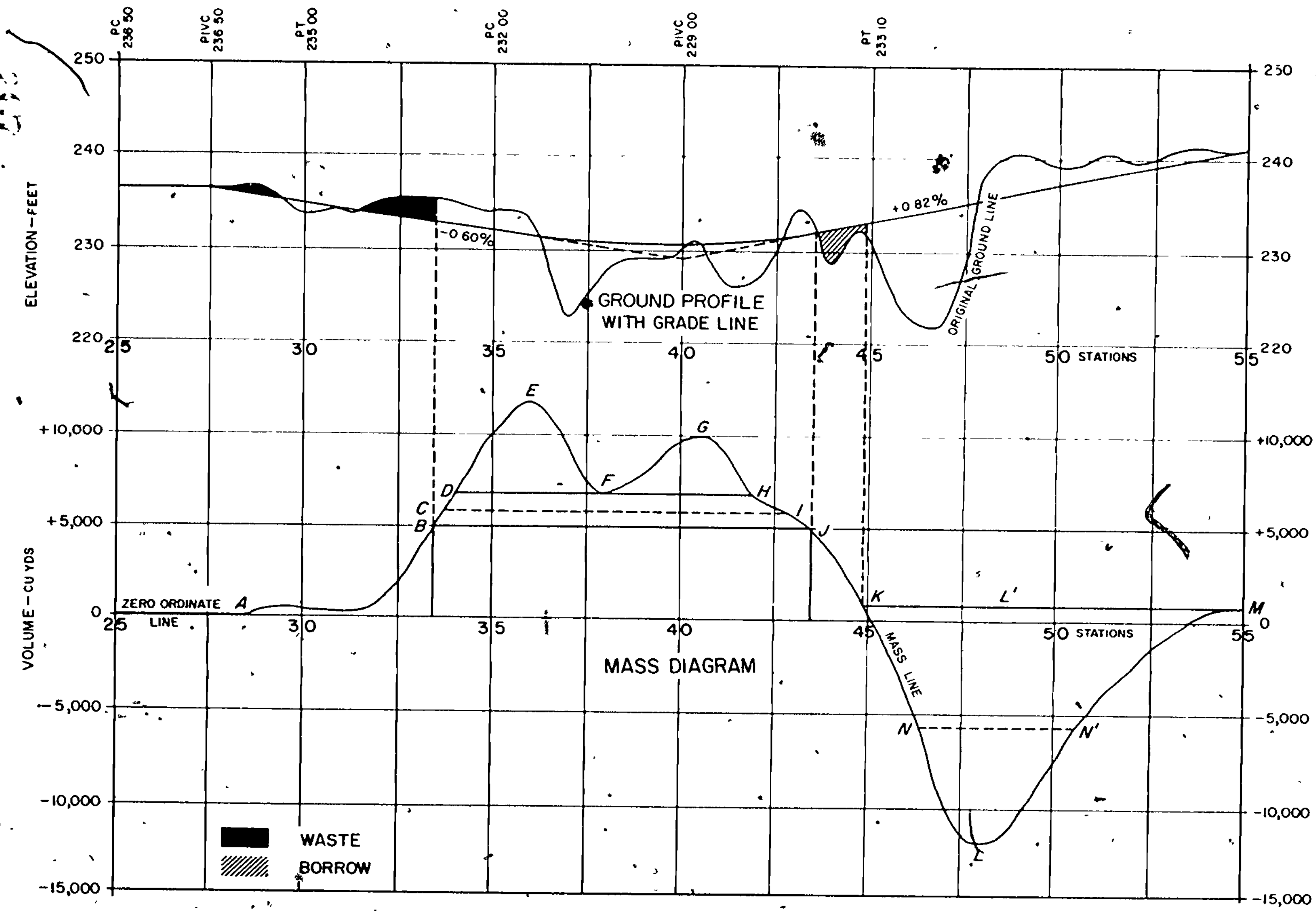
(1) Station	(2) End area: Cut sq ft	(2) End area: Fill sq ft	(3) Excavation cu. yd	(3) Embankment cu. yd	(4) Stripping: Cut section cu. yd	(4) Stripping: Fill section cu yd	(5) Net excavation cu. yd	(6) Excavation x factor (0 9) cu yd	(7) Net embankment cu yd.	(8) Balanced yardage* cu. yd	(9) Algebraic sum	(10) Ordinate
28+00	116	9	537	93			537	483	93	93	+390	0
29+00	174	41	363	333	...		363	327	333	327	−6	+390
30+00	22	139	778	674			778	700	674	674	+26	+384
31+75	218	68	693	170			693	624	170	170	+454	+410
32+20	614	136	2,622	201	244	42	2,378	2,140	243	243	+1,897	+864
33+00	1,156	0	4,167	0	342	0	3,825	3,442	0	0	+3,442	+2,761
33+90	1,345	0	4,551	0	416	0	4,135	3,722	0	0	+3,722	+6,203
35+00	889	0	2,459	130	308	33	2,151	1,936	163	163	+1,773	+9,925
36+00	438	70	630	652	93	99	537	483	751	483	−268	+11,69
36+50	241	635	604	2,102	64	171	540	486	2,273	486	−1,787	+11,43
37+00	411	1,634	2,918	5,015	197	306	2,721	2,449	5,321	2,449	−2,872	+9,643
38+00	1,165	1,074	4,133	2,233	278	197	3,855	3,470	2,430	2,430	+1,040	+6,771
39+00	1,066	132	2,915	467	278	136	2,637	2,373	603	603	+1,770	+7,811
40+00	508	119	879	212	177	65	702	632	277	277	+355	+9,581
40+65	222	56	166	331	69	46	97	87	344	87	−257	+9,936
41+00	35	454	196	2,830	100	250	96	86	3,080	86	−2,994	+9,679
42+00	71	1,074	1,730	2,000	211	153	1,519	1,367	2,153	1,367	−786	+6,685
43+00	862	5	1,918	2,937	217	187	1,701	1,531	3,124	1,531	−1,593	+5,899
44+00	174	1,582	679	3,013	107	204	572	515	3,217	515	−2,702	+4,306
44+70	349	742	2,480	6,673	242	307	2,238	2,014	6,980	2,014	−4,966	+1,604
46+00	680	2,029	2,037	7,307	172	286	1,865	1,678	7,593	1,678	−5,915	−3,362
47+00	419	1,916	2,922	4,656	206	241	2,716	2,444	4,897	2,444	−2,453	−9,277
48+00	1,159	598	3,580	1,780	202	142	3,378	3,040	1,922	1,922	+1,118	−11,73
48+90	989	470	4,897	957	356	76	4,541	4,087	1,033	1,033	+3,054	−10,61
50+00	1,415	0	3,926	0	389	0	3,537	3,183	0	0	+3,183	−7,558
51+00	704	0	2,511	0	372	0	2,139	1,925	0	0	+1,925	−4,375
52+00	651	0	2,493	0	364	0	2,129	1,916	0	0	+1,916	−2,450
53+00	695	0	1,496	74	275	50	1,221	1,099	124	124	+975	−534
54+00	112	41	733	74	256	50	477	429	124	124	+305	+441
55+00	283	0										+746
Grand total			60,013	44,914	5,935	3,041	54,078	48,668	47,922	21,323		

* Balanced yardage (compacted) between stations is used only for purposes of estimating construction time and the scheduling of men and equipment.

Panel 5-7. Soil Conversion Factors.

Soil type	Initial condition	Converted to		
		In-place	Loose	Compacted
Sand	In-place	—	1.11	.95
	Loose	.90	—	.86
	Compacted	1.05	1.17	—
Common earth	In-place	—	1.25	.90
	Loose	.80	—	.72
	Compacted	1.11	1.39	—
Clay	In-place	—	1.43	.90
	Loose	.70	—	.63
	Compacted	1.11	1.59	—
Rock	In-place	—	1.50	1.30
	Loose	.67	—	.87
	Compacted	.77	1.15	—

Panel 5-8. Mass Diagram in Combination with Centerline and Grade Profiles.



Panel 5-9. Computation of Earthwork Volume by Arithmetic Straight-line Proportion Using Mass Diagram and Computation Sheet.

To find the volume of earthwork between stations K and M proceed as follows:

(1) Take the largest ordinate below the zero ordinate level (11,730).

(2) Add to this volume the value of the ordinate above the zero line (the value of M at 55 or 746).

```
 11,730
+   746
-------
 12,476  yardage without balanced material
```

(3) Add balanced values (col 8) from station 46 + 00 to 55 + 00. This is 7325.

(4) Using straight line proportion between 44 + 70 and 46 + 00 the balanced yardage between 44 + 92 and 46 + 00 is determined to be 1659.

(5)
```
Add 1659                              12,476
 to 7325                             + 8,984
    ----                             -------
    8984 total balanced yardage       21,460
```

LESSON 5

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

1. Using the table in panel 5-1, what would the volume (cu yd) of earthwork in a cut 300 feet in length, 26 feet wide at the base with 1½ to 1 slopes and an average depth of 4 feet (level section)? (frame 5-7 and panel 5-1)

2. Using the triangle method for the cross section shown in panel 5-2, what is the combined total area in square feet of triangles 7, 8, 9, and 10? (frame 5-24 and panel 5-2)

3. In the average-end-area method, a table can be used which requires only the sum of the end areas to find the volume. Referring to panel 5-6, what would be the volume of cut in cubic yards (round off to nearest 10ths) between stations 33 + 00 and 33 + 90? (use also panel 5-3) (frames 5-30, 5-32, panels 5-3 and 5-6)

4. Estimates of runway earthwork require the preparation of special tables. In preparing a table for airfield earthwork estimates, what cut-to-fill factor is used for fills over 2 feet high? Under 2 feet? (panels 5-4 and frames 5-40 and 5-41)

5. The mass diagram is a graph of 2 variables plotted at right angles. What are these two variables and how are they plotted (abscissa and ordinate)? (frame 5-59)

6. Because of shrinkage, conversion factors must be applied in balancing grades between cuts and embankments. If 1200 cubic yards of fill are required for an embankment, how many cubic yards of in-place sand should be removed from the excavation to balance the cut against the compacted fill? (frame 5-76 and panel 5-7)

7. The balance line of a mass diagram is drawn parallel to the datum line. What criteria determines the maximum length of a balance line on a mass diagram? (frame 5-94)

8. If the mass diagram represents the algebraic summation of net yardage from station to station, what does the maximum ordinate above or below any balance line represent? (frame 5-103)

9. Referring to the mass diagram (panel 5-8), the haul for the fill section KL should be made from the embankment LM. What would be the direction of haul? (frame 5-115)

10. There are two ways of determining balanced yardage in estimating time, equipment, and personnel requirements for earth moving projects. One is by selection from column 8, computation work sheet. What is the other? (frames 5-86 and 5-117)

11. The purposes of earthwork computations are to finish final grades, to balance cuts and fills, and to plan the most economical haul of material. Which materials (making up subgrade and base course) are included or excluded in earthwork computations? (frame 5-2)

12. At what intervals are cross sections plotted and what are the exceptions? (frames 5-12 to 5-14)

13. Using the "triangle method" of determining cross section areas, what is the area of the cross section shown in Panel 5-2 from five feet left of the centerline to thirty feet right of the centerline? (frame 5-23)

14. Describe the "counting the squares" method of approximating cross section areas. (frame 5-18)

15. Assuming a cut section has the dimension H equal to 2 feet (panel 5-4), what would be the volume of fill that can be obtained from that section if it were 350 feet long? (panel 5-4, frame 5-41)

16. What is the purpose of establishing a tentative runway grade line? (frames 5-42 to 5-44)

17. Describe the method discussed in the text for plotting a tentative runway grade line. (frame 5-45 to 5-49)

18. There are two methods by which borrow pit volumes maybe computed. The final step however is common to both. What is this step? (frames 5-50, 5-52)

19. Using panel 5-6, what is the volume of excavation in cubic yards between stations 41 + 00 and 42 + 00? (panel 5-6 and frame 5-67)

20. Give the following information of an assumed station:

Excavation (cu yd) = 2,169
Embankment (cu yd) = 1,365

Stripping volume

Cut section (cu yd) = 214

Fill section (cu yd) = 146

What is the net excavation in cubic yards for this station? Net embankment? (frames 5-71, 5-72 and panel 5-6)

21. Referring to panel 5-6, how are the values of column 6 computed? Give name and number of columns involved. (panel 5-6, frame 5-74)

22. The algebraic sums of column 9 of panel 5-6 have both positive and negative values. What is the meaning of the positive and negative signs. (frame 5-60)

23. What is the meaning of an ascending or descending mass line in a diagram? (frame 5-92)

24. Mass lines will enventually form summit humps and sag humps on the diagram. Indicate the direction of haul in both summit humps and sag humps. (frame 5-93)

25. How may the average length of haul be approximated from the mass diagram? (frame 5-113)

LESSON 6

DRAINAGE

CREDIT HOURS ------------------ 2

TEXT ASSIGNMENT ---------------- Attached Memorandum.

LESSON OBJECTIVES

Upon completion of this lesson, you should in the following subjects areas, be able to:

1. **Drainage in site selection** — Discuss the value of adequate drainage knowing that poor drainage is one of the major causes of road and airfield failure.

2. **Slopes and ditches for surface drainage** — Describe the need to properly assign the correct slope to the corresponding requirements and make recommendations of slopes; describe the types of ditches, their characteristics, and uses for proper surface drainage; calculate the number, spacing, and height of check dams when needed.

3. **Cross drainage — Culverts** — Discuss the purpose of culverts, the practices of using corrugated metal pipe, the use of the log box culverts, and other expedient methods.

4. **Alinement and size of culverts** — Discuss the positioning and alining of culverts, the hasty methods of determining the cross sectional areas of culvert requirements, the over design factor, the use of Talbots formula for culvert cross sectional areas, and finally the calculation of number of pipes required.

5. **Length and cover of culverts** — Discuss the important considerations of length, the rules for depth, multiple culverts and pipe cover requirements for airfields.

6. **Grade and foundation of culvert** — Support the selection of a grade to be used in culvert construction citing minimum and maximum requirements and discuss the preparations for foundation and fill.

7. **Subsurface drainage** — Discuss the purpose of subsurface drainage, considerations of placement, and the two types of subsurface trenches (French and tile).

CONTENTS

Frames

Set 1. Importance of Drainage in Site Selection.

FRAME 6-1.

Poor drainage is a primary cause of road and airfield failure. Practically any soil, when dry, will support a vehicle, but most roads and runways fail when the base course and subgrade become saturated. The primary cause of road and runway failure is ______________ ______________.

---

(2) (6-18)

FRAME 6-19.

According to panel 6-5, the spacing is determined by the formula:

$$S = \frac{100\ H}{A - B}$$

Based on panel 6-4, (1) the value for H must be between ______________ and ______________ feet; (2) the value for B should be between ______________ and ______________ percent.

(equal) (cross sectional) 6-36)

FRAME 6-37.

In areas where weather conditions are erratic or little known, culvert sizes may be overdesigned as much as 50 to 100 percent to allow for unusual conditions. To allow for ______________ conditions culverts are ______________ from ______________ to ______________ percent.

(0.5%) (6-54)

FRAME 6-55.

A maximum grade of 2 percent is used when a bottomless or earth floor culvert is employed. This is to prevent scouring or erosion of the bottom. Earth floor or bottomless culverts are built with a maximum grade of ______________. When CMP or a box culvert is employed a maximum grade of ______________ is used.

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(poor) (drainage) (6-1)

FRAME 6-2.

Roads that cut straight across the terrain without regard for the natural slopes and stream lines usually require considerable construction — intercepter ditches and cross-drainage facilities. Steep grades normally require extensive erosion-control work on the side ditches. The problem of adequate ________ is one of the most important encountered in the location, design, and construction of roads and airfields.

---

(1) 1, 3 (2) 2, 2.5 (6-19)

FRAME 6-20.

The height of the checkdam is determined by the formula:

$$H = \frac{S\ (A - B)}{100}$$

If the spacing between two checkdams is 50 feet, a 7% ditch slope can be reduced to a 2% slope on the surface of the water. In this installation, the height of checkdams would be ________________ feet, which is within the permissible limits.

(unusual) (overdesigned) (50,100) (6-37)

FRAME 6-38.

The selection of pipe culvert sizes depends on the rate of flow of water to be carried, or rate of runoff, and the height of the road above the streambed. Rate of flow is one factor in determining the ________________ of pipe culverts. A limiting factor to pipe size would be the ________________ of road above the streambed.

(2%) (4%) (6-55)

FRAME 6-56.

In all cases, the outlet end of the culvert should be protected with riprap or sod to prevent ________________.

(drainage) (6-2)

FRAME 6-3.

The greatest single cause of work stoppages on road and airfield construction projects is wet weather. In the construction sequence, drainage is listed immediately after the clearing and grubbing phase. Drainage must be considered during the early construction phase to minimize work stoppages due to

________________ ________________.

$(H = \frac{50\ (7\text{-}2)}{100})$ (= 2.5) (6-20)

FRAME 6-21.

To determine the number of checkdams required, divide the length of the ditch by the spacing (panel 6-6). The first checkdam is always located at the bottom of the adverse grade. To reduce the slope of an existing 550-foot ditch from 4 percent to 2 percent with checkdams, each having a 1 foot drop, would require ________________ checkdams.

(size) (height) (6-38)

FRAME 6-39.

Multiple pipe culverts are used to increase the waterway area without increasing the height (size) of the culvert. The use of ______________________ culverts is necessary when the road surface is only a short distance above the streambed or when the natural stream channel is relatively wide and shallow. Multiple pipes should all be of the same diameter.

(scouring) (6-56)

FRAME 6-57.

Culverts are constructed on a firm well-compacted soil foundation, except that box culverts may be placed on suitable rock foundations where such is encountered. The foundation is always shaped to fit, or bed, one-tenth of the diameter of pipe culverts (panel 6-20). A pipe culvert is placed in a well compacted soil foundation ______________ to bed ______________ of the pipe diameter.

(wet) (weather) (6-3)

FRAME 6-4.

Drainage construction must precede earthwork for two reasons. First, most culverts must be installed in order to allow earthwork operations to progress without interuption; second, fills and cuts must be protected from the effects of rain and overland flow during all phases of construction. Cuts and fills must be ______________________ from overland flow during all phases of construction.

---

(11) (see panel 6-6) (6-21)

FRAME 6-22.

The weir notch is the discharge slot at the top of the checkdam. As stated before, it must be big enough to discharge the anticipated runoff. As shown in panel 6-7, the size of the weir notch can be derived from the formula:

$$Q = CLH^{3/2}$$

For practical considerations, the depth of flow may be assumed and the length of slot then calculated, or the length of slot may be assumed and the depth of flow then calculated. Note that as a safety factor the slot is always constructed ____________________ foot deeper than the depth of flow.

(multiple pipe) (6-39)

FRAME 6-40.

In determining the required area of culverts, as previously stated, the culvert area must ________________ the cross-sectional area of the upstream ditch (streambed). Required areas of culverts may be calculated by estimating (hasty method) the cross-sectional area of the upstream channel or by applying an approximate method (Talbot's formula).

(shaped) $(\frac{1}{10})$ **(6-57).**

FRAME 6-58.

According to panel 6-20, the fill around pipe culverts should be ________ placed and tamped to a depth of ________________ ________________.

(protected) (6-4)

FRAME 6-5.

In fill operations, the sides (slopes) of the embankment must be protected from erosion and the embankment itself should be crowned and backbladed or smoothed off whenever it is to be left for any length of time or a storm is imminent. In fills, the ______________ of the embankment must be protected from erosion.

(0.5 or ½) (6-22)

FRAME 6-23.

If the flow in a ditch is found to be 5 cubic feet per second and assuming L = 2 feet, the weir notch should be ______________ feet deep.

(equal) (6-40)

FRAME 6-41.

The quickest hasty method of determining the size of waterway is by the reconnaissance method. Three simple measurements of an existing streambed will give the ______ ______ area. To this is added a 100 percent safety factor. The culvert is designed with a waterway equal to the area of the channel (ditch or streambed) plus the ______ ______ safety factor.

(hand) (½D (diameter)) (6-58)

FRAME 6-59.

Placement of drum culverts should be done with care. A cradle of wood or concrete will usually be required to provide an adequate ______. To avoid collapse from earth and traffic loads, place the the entire culvert in as narrow a trench as possible. As in the case of pipe culverts, backfill around drum culverts should be well tamped, particularly on the lower ______.

(slopes) (sides) (6-5)

FRAME 6-6.

In cutting operations, the center of the cut should be kept high to facilitate runoff. There must always be some type of side ditch, cut to drain along the sides of a working cut. During construction, the ________________ of a cut should be kept ________________ and a ________________ ditch should be provided.

Set 3. Cross Drainage – Culverts.

(1.4 ft) (6-23)

FRAME 6-24.

Whenever natural drainage channels cannot be diverted economically from roads, taxiways, and occassionally runways, facilities must be provided to permit cross-drainage to flow under them. Culverts are used for this purpose. They provide cross-drainage at low points in a fill, provide ditch relief, and continue side ditches at intersections. Their ease of construction makes them more desirable than small bridges under many conditions. When water has to be drained across the line of a road or taxiway ________________ are usually built.

(cross sectional) (100%) (6-41)

FRAME 6-42.

As shown in panel 6-12, (1) the formula for calculating the area of a channel is ______________; (2) the design area for the given example should be ______________ square feet.

Set 7. Subsurface Drainage.

(foundation) (half) (6-59)

FRAME 6-60.

When rain falls on the surface of the earth, a portion percolates or infiltrates into the earth. This accumulates in voids in the soil or rock beneath the surface and becomes what is called ground water. The surface of this layer of water which roughly parallels the surface of the earth, is called the water table. The water table is generally close to the surface in valleys and well below the surface on the hills or ridges. If the water table level is higher than permitted by construction requirements, it is lowered by subsurface drainage. The object of ______________ ______________ is to lower the ______________ ______________ by tapping the ground water and carrying it off in a pipe or ditch.

(center) (high) (side) (6-6)

FRAME 6-7.

The first step in the design of drainage facilities for roads or airfields is to locate those areas that might contribute surface or subsurface flow to the site. The second and most important step is to locate all the existing water courses that can be used to carry this flow from the site. In the design of road or airfield drainage facilities, the most important step is to locate existing ________ ________ that may be used to carry the ________________ away from the site.

(culverts) (6-24)

FRAME 6-25.

Most pipes used for culvert construction are made of either reinforced concrete, cast iron, or corrugated galvanized metal. Pre-formed corrugated metal pipe (CMP) is the easiest to place. CMP is produced in standard sizes ranging from 8 to 84 inches in diameter; nestable CMP (flanged half sections, bolted together in the field) commonly range from 12 to 48-inch diameter in 6-inch increments, but sizes of 60- and 72-inch diameter are also supplied in the theater of operations. Because it is easier to place, nestable ________________ is the most common item found in supply overseas.

(1) $\frac{W_1 + W_2}{2} \times H$ (2) 32 (6-42)

FRAME 6-43.

Another hasty method of estimating the waterway or culvert area is to question local inhabitants about climatic conditions and location of high water mark when the stream is in flood. The size of the channel is then ________ on the basis of the reported flow, topography of the watershed, and the appearance of the channel. A ________ ________ safety factor is added the same as in application of the reconnaissance method.

(subsurface drainage) (water table) (6-60)

FRAME 6-61.

In road or airfield construction the water table should be a minimum of 5 feet below the facility. A site which requires extensive ________ ________ should first be weighed against two alternatives—relocation of the facility to higher ground or the use of fill to raise the facility to the proper height above the ________ ________.

Set 2. Slopes and Ditches for Surface Drainage.

(water) (courses) (flow) (6-7)

FRAME 6-8.

Standing water on road, runway, and parking-area surfaces not only decreases operating efficiency but will eventually saturate the subgrade, causing failure. Sheet flow (moving water) that is too deep or moving too fast will erode the surface over which it moves. Surfaces are built with gentle slopes designed to remove ____________________ water and control ____________________ flow with minimum damage to surfaces and subgrades.

(CMP) (6-25)

FRAME 6-26.

When pipe culverts are NOT readily available, box culverts can be used. They are constructed with a square or rectangular cross section and may be built with logs, sized timber, or dimensioned lumber. Box culverts must be designed to prevent side as well as roof collapse. ____________________ culverts may be used in lieu of pipe culverts but must be designed to prevent both ____________________ and ____________________ collapse.

(estimated) (100%) (6-43)

FRAME 6-44.

Talbot's formula (panel 6-13) may be used as an approximate method of computing the cross-sectional area of a culvert. Note that the accuracy of the formula is dependent on the selection of the ______________ ______________. To simplify the use of Talbot's formula, a nomograph (panel 6-14) is used to determine the required waterway after the value of C has been estimated. In the given example, the required area of culvert is ________________ square feet. This is the correct value to be used and no safety factor need be added.

(subsurface drainage) (water table) (6-61)

FRAME 6-62.

In many cases when a high water table is encountered, the problem may be solved by relocating the road or airfield in different terrain, if possible, preferably on the ________________. It may prove the cheapest as well as quickest solution. If possible, the ________________ of a road or airfield may be the simplest solution to a water-table problem.

(standing or surface) (sheet) (6-8)

FRAME 6-9.

The steepness of the slope or crown required to remove surface water depends on the impermeability of the surface material. Concrete and asphalt surfaces, for example, require less slope than gravel or earth surfaces because water does not penetrate them as readily. Panel 6-1 shows recommended cross slopes for roads and runways. Note that earth and gravel surfaces require a transverse slope of ____________ to ____________ inch per foot, while paved surfaces require only ____________ to ____________ inch per foot.

(box) (side) (roof) (6-26)

FRAME 6-27.

Log box culverts can be made in several ways. Based on panel 6-8—which shows the best method of construction : (1) the side logs run along the ____________ of the culvert with the logs which form the top and bottom laid at ____________ angles to them; (2) ____________ and ____________ are placed inside the culvert to provide stability; (3) when low bearing soil is encountered, ____________ and ____________ must be used.

(coefficient C) (42) (6-44)

FRAME 6-45.

After the required design area of culvert is known, a box culvert can be designed accordingly. In the design of pipe culverts, the size and number of ______________ ______ can be found by referring to panel 6-15. For example, the waterway area of an 8-inch pipe is 0.35 square feet. The waterway area of an 18-inch pipe is ______________ square feet.

(ridges) (relocation) (6-62)

FRAME 6-63.

Another method of obtaining a dry subgrade is to raise the roadbed or runway above the water table. This method may sometimes be very costly in time and material. However, if fill material is plentiful, it may well be the most feasible solution. A roadbed should be located at least ______________ feet above the water table.

(½)(¾)(¼)(½) (6-9)

FRAME 6-10.

In addition to the transverse slopes shown in panel 6-1, a minimum longitudinal grade is normally established for roads and runways. This grade naturally corresponds to the grade of the longitudinal ditch to obtain balanced removal of water. For military roads, no longitudinal grade is required for fill sections; a 0.5% minimum is usually adequate for cut sections. Proper removal of surface water requires that surfaces be sloped both laterally and ________________.

---

(1) length, right (2) stakes, spreaders (3) sleepers, stringers (6-27)

FRAME 6-28.

Panel 6-9 shows an alternate method of constructing log culverts. This is an excellent method but takes considerable time to build. Note, in contrast to the standard log culvert; the side logs are placed ________________ to the flow line and fit into ________________ in the logs forming the top and bottom.

(pipes) (1.77) (6-45)

FRAME 6-46.

In most cases, the selection of pipe is limited to standard sizes (panel 6-15). To find the number of pipes required for a culvert, take the required waterway area and divide it by the waterway area of the pipe selected. Ditch or channel area divided by _______ area gives the number of pipes needed.

---

(5) (6-63)

FRAME 6-64.

To intercept the ground water, drains must be located on the upstream side of the project and must extend down below the water table. Subsurface drains are located _______ from the project and at a level _______ the water table.

(longitudinally) (6-10)

FRAME 6-11.

Ditches are normally used to intercept surface runoff and carry it to a convenient disposal area. Those shown in panel 6-2 are quickly constructed with a motorized grader. The trapezoidal ditch requires a more skillful operator, but can be built with varying base width to carry greater volumes of water, when required. It is always used in sandy or other soil that erodes easily. For ease of construction, however, the ___ ___ ___ ditch is normally used.

(perpendicular) (notches) (6-28)

FRAME 6-29.

Another type of ___ ___ culvert is one built with sized timber or dimensional lumber. This is constructed either with outside bracing or collars or with internal bracing. Internal bracing will reduce the water capacity but should be used whenever possible because it provides more strength and rigidity than outside bracing. ___ ___ bracing is preferred to ___ bracing in the construction of box culverts built with sized timber or dimensional lumber.

Set 5. Length and Cover of Culverts.

(pipe) (6-46)

FRAME 6-47.

The length of culvert (box or pipe) is an important consideration. Culverts must be long enough to extend completely through fills to the point where the fill slope meets the ground or streambed (panel 6-16). Culverts must be ________________ to prevent earth from being washed into them from the fill and also to prevent the embankment from being scoured by the water as it leaves the culvert.

(upstream) (below) (6-64)

FRAME 6-65.

Where springs are encountered they should be capped and the water carried off in a pipe. The object of subsurface drainage in this case is to ____________ the water table by intercepting the ____________ ____________.

("V") (6-11)

FRAME 6-12.

Both sides of a ditch need not have the same slope. However, if a deep "V" ditch 2 feet deep is built with maximum slope of both sides, the ditch will be ________________ feet wide.

(box) (internal) (outside) (6-29)

FRAME 6-30.

Although the resulting structures are not as strong as CMP or box culverts, expedient drainage structures can be built using steel (oil, gasoline, or asphalt) drums. Steel ________________ are useful ________________ for forming drainage structures.

(long enough) (6-47)

FRAME 6-48.

To minimize ________________ at the downstream end culverts should be 1 or 2 feet longer than otherwise required, with the added length on the discharge end (panel 6-17). If headwalls are constructed at the discharge end, the ________________ of culvert may be shortened, but it usually takes less time, labor, and materials to build longer culverts.

(lower) (ground water) (6-65)

FRAME 6-66.

Subsurface drainage may sometimes be accomplished by the use of deep open (V) ditches. These ditches are easily built, are readily enlarged, and provide positive interception of subsurface water before it reaches the area being protected. Deep ________________ ________________ serve the purpose of ________________ ground water.

(4) (6-12)

FRAME 6-13.

Side slopes in ditches adjoining runways require special consideration. More serious accidents may be avoided if aircraft missing the runway can roll through ditches without overturning or damaging landing gear. Panel 6-3 shows a typical side ditch for a military airfield. Note that this __________ __________ ditch limits the depth of flow to a maximum of __________ inches.

(drums) (expedients) (6-30)

FRAME 6-31.

In preparing steel drums for constructing expedient drainage structures, the pneumatic metal drum opener does an excellent job in removing drum heads. After the ends are removed, a continuous pipe is formed by tack welding or wiring the drums together. Expedient drainage structures are built by tack __________ or __________ steel drums together to form a continuous pipe.

(scouring), (length) (6-48)

FRAME 6-49.

In military construction it is desirable to ________________ culverts beyond fills rather than build extensive inlet and outlet facilities. In some instances, scouring can be ________________ by constructing a toe ditch to carry the water off the embankment (fill slope).

(open or V ditches) (intercepting) (6-66)

FRAME 6-67.

Deep open ditches are not usually constructed in long stretches but are more commonly employed in short stretches at critical points. However, in many cases, such ditches are a traffic hazard and they are also subject to erosion. Deep open ditches are usually used only on ________________ ________________ of a project where the water table does not have to be lowered over a substantial portion of the project.

(shallow) (V) (3) (6-13)

FRAME 6-14.

The motorized grader can be used to construct any of the three types of drainage ditches, depending on the specific requirements. For normal road construction requirements the ____________________ ____________________ ditch is most suitable; where extra capacity is needed or where the soil erodes easily the ____________ ditch is best; the ______________ ______________ ditch is built near airfield runways.

Set 4. Alinement and Size of Culverts.

(welding) (wiring) (6-31)

FRAME 6-32.

In placing culverts, an effort should be made to continue the original direction of flow of the water. A change in direction of stream flow at the upper end of the culvert is objectionable primarily because it may result in erosion of the sides of the channel around the entrance. When positioning a culvert, the ____________________ of flow should be continued in its original direction, if possible.

303

(extend) (prevented) (6-49)

FRAME 6-50.

In order to prevent the collapse of the culvert under traffic loads, it should have adequate earth cover (panel 6-18). Pipe culverts under military roads should have at least (1) ______________ inches of cover for sizes smaller than 24 inches in diameter, (2) ______________ the diameter for larger sizes. The preferred cover for a box culvert is (3) ______________ inches and cover for a drum culvert should be not less than (4) ______________ inches.

(short) (stretches) (6-67)

FRAME 6-68.

In those cases where right-of-way problems, traffic situations, and erosion difficulties make the use of open ditches impractical, it may be necessary to use a system of subsurface drains. In most cases, ______________ ______________ are used in place of deep ______________ ______________.

(deep V) (trapezoidal) (shallow V) (6-14)

FRAME 6-15.

Longitudinal (side) ditches alongside a road or runway are referred to as collection ditches. Diversion ditches move the water from collection ditches to disposal areas. Where a relatively large area drains toward a facility, interceptor ditches are needed to prevent erosion or actual flooding of the facility. Classified according to their function there are three types of ditches: ________, ________, and ________.

(direction) (6-32)

FRAME 6-33.

Culverts are alined in various ways, depending on the terrain and the stream channel. When possible, place culverts at right angles to the centerline of the road or taxiway. Placing culverts at ______________ ______________ to the centerline is particularly advisable on steep mountain streams or streams with high approach velocities.

(1) 12 (2) 1/2 (3) 18 (4) 36 (6-50)

FRAME 6-51.

When placing a pipe culvert ~~in~~ a fill, consideration must be given to the maximum size pipe allowable in the fill so that the minimum cover is maintained. As shown in panel 6-18 (1) the formula for calculating maximum size pipe allowable is ______________: (2) the minimum cover for the given example should be ______________ inches.

(subsurface) (drains) (open) (ditches) (6-68)

FRAME 6-69.

The two types of subsurface drains normally used are the French or blind drain and the tile drain. The two types of subsurface drains to remember are the blind or ______________ drain and ______________ drain.

(collection) (diversion) (interceptor) (6-15)

FRAME 6-16.

A minimum slope of 0.5% is necessary to make ditches self-cleaning; the maximum desirable slope is set at about 4%. When the slope becomes greater than the desired maximum, the ditch must be lined with riprap, sodded, or paved. Normally, the difference in elevation per 100 feet of ditch should be not more than ________________ feet.

(right angles) (6-33)

FRAME 6-34.

If a meandering stream is encountered, the culvert should be installed at the best possible location and the stream channel straightened as necessary (panel 6-10). Some construction such as building ________________ and digging ________________ ________________ for shifting the stream to proper alinement may be required.

(D[illegible] 2 3 F) (24) (6-51)

FRAME 6-52.

If multiple culverts are used, they should be spaced a distance of one half the diameter apart. This is done to provide space for tamping a back fill as well as preventing the culverts from crushing each other from the sides. If 2 culverts of 40-inch diameter are used they should be spaced ______ inches apart.

(French) (tile) (6-69)

FRAME 6-70.

Blind or French drains are constructed by filling a ditch or trench with stone or crushed rock (panel 6-21). The top of the trench is then covered with a well compacted soil forming an impervious seal to exclude surface water. The ______________ drain is filled with __________ ______ rocks near the bottom and ______________ ones near the top.

(4) (6-16)

FRAME 6-17.

On sidehill cuts and steep grades, checkdams are placed in side ditches to reduce the rate-of-flow (slow the water) and prevent erosion. They are built of timber, sandbags, concrete, rock, or other similar materials. Checkdams are built to reduce the ______________ ______________ ______________ and prevent ______________ in side ditches.

(dams) (new channels) (6-34)

FRAME 6-35.

On sidehill roads or wherever roads intercept surface water, either in cut or fill, the water is drained to the low side of the road, and, if possible, away from the road by ditch-relief culverts (panel 6-11). Ditch-relief culverts should be installed at an angle of ______________ to the centerline, to allow a more direct entrance of water into the culvert. On 5-percent grades, ditch-relief culverts should be placed about ______________ feet apart; on 8-percent grades, ______________ feet apart.

(20) (6-52)

FRAME 6-53.

Minimum cover for culverts on airfields can be found in panel 6-19. A CMP culvert of 14 gage and 12 inches in diameter designed to carry an 80,000 pound plane, should have at least ________________ feet of cover.

(French) (large) (small) (6-70)

FRAME 6-71.

In the French drain, the ground water enters the trench from the sides and percolates through the large stone at the bottom of the trench until it reaches a point where it can be dumped into a diversion ditch. Water enters the French drain through the ________________ of the trench: the top of the drain is ________________ to exclude ________________ water.

(rate-of-flow) (erosion) (6-17)

FRAME 6-18.

Side slopes of the ditch immediately above and below checkdams (panel 6-4) require protection from erosion and scouring. To accomplish this, a weir notch big enough to discharge the anticipated runoff is cut in the middle of the checkdam to prevent backed-up water from cutting at the edges of the checkdam. An apron, extending from the downstream face of the checkdam, is needed to prevent scouring. Checkdams must extend at least ____________ feet into the sides and bottom of the ditch.

Turn back to bottom of page 6-3.

(60°) (500,300) (6-35)

FRAME 6-36.

Size is a major consideration in culvert construction. The cross-sectional area of culverts should be at least equal to that of upstream ditches or stream channels. The minimum area of culvert is at least ____________ to the ____________ ____________ area of upstream ditches.

Turn back to top of page 6-4.

Set 6. Grade and Foundation of Culverts.

(1.5) (6-53)

FRAME 6-54.

Normally, culverts are placed on the same grade (slope) as the natural and artificial drainage channels which discharge into them. To prevent the accumulation of sediment in pipes, it is generally desirable to use grades from 2 to 4 percent; in extreme cases, where the fall of the terrain requires it, 0.5 percent grade may be used as the absolute minimum. Adequate flow to prevent silt settling in pipe culverts requires a ________ minimum grade.

Turn back to bottom of page 6-4.

(sides) (sealed) (surface) (6-71)

FRAME 6-72.

A tile drain is the same as the French drain except that the trench may be filled with gravel in lieu of crushed stone and a pipe is placed near the bottom (panel 6-21). The pipe is usually 6 inches in diameter although 8- and 10-inches pipes are also used. The tile drain differs from the French drain in that a ________________ is employed to carry the excess water away.

(pipe) (6-72)

FRAME 6-73.

The most common form of subsurface piping is perforated pipe. In cases where the perforations do not extend completely around the circumference of the pipe, the pipe is generally laid with the holes down and with the joints closed. Semiperforated pipe is always laid with the holes ________________ and the joints are ________________.

(down) (closed) (6-73)

FRAME 6-74.

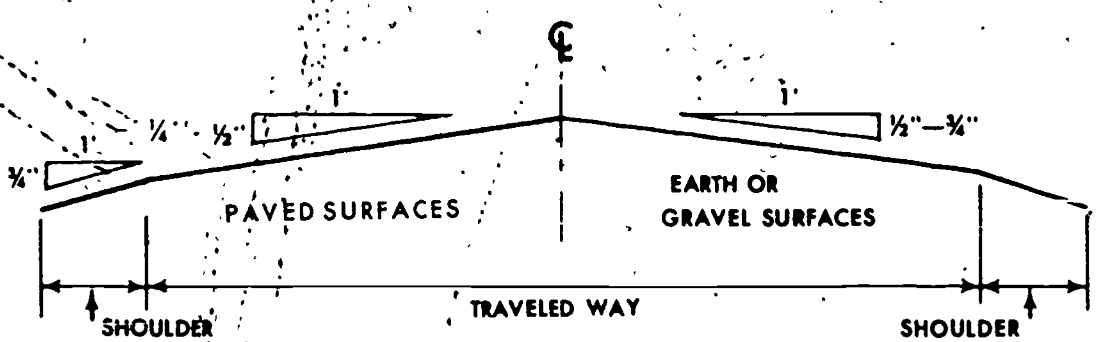
Corrugated metal, vitrified clay, and nonreinforced concrete pipe may also be used for subsurface piping. Such pipe is laid with open joints, or the top half may be sealed with $\frac{1}{2}$-inch to $\frac{1}{4}$-inch openings on the bottom. The minimum grade for all subsurface piping is 0.3 percent. Either ______________ pipe or pipes laid with ______________________________ may be used in a tile drain.

(perforated) (open joints) (6-74)

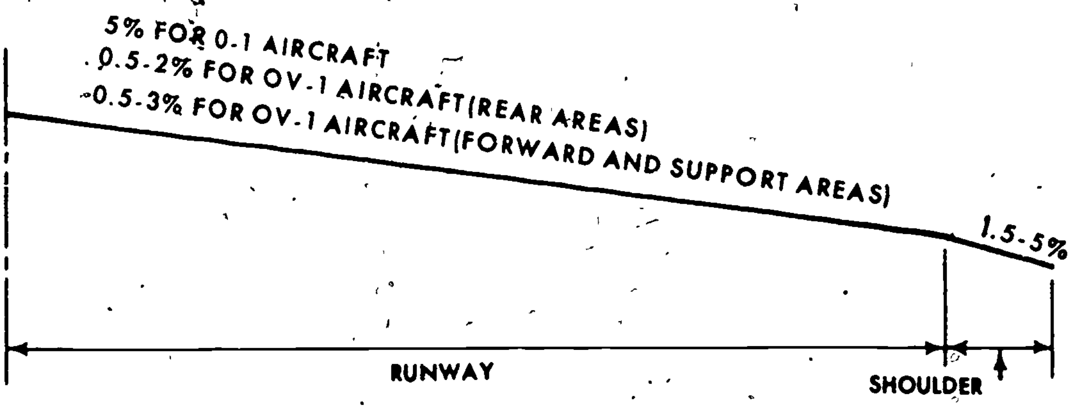
END OF FRAMES

PANELS AND SELF TEST·FOLLOW

Panel 6-1. Military Road and Airfield Cross Slopes.

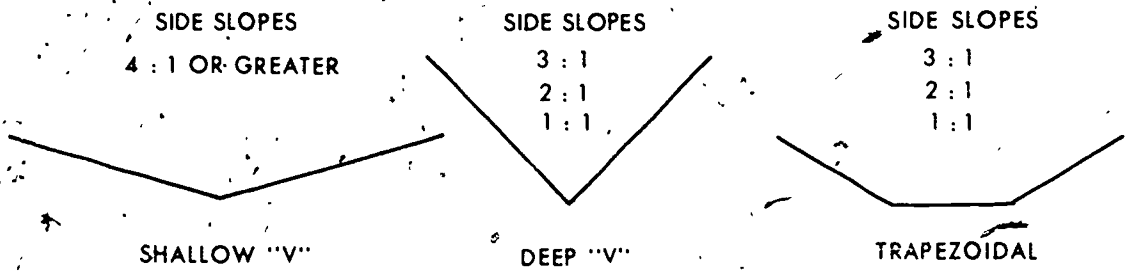


CENTER CROWN SECTION OF ROADS

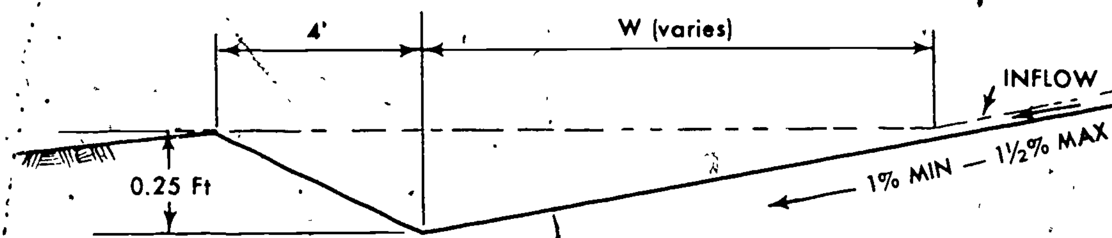


CENTER CROWN SECTION OF AIRFIELDS

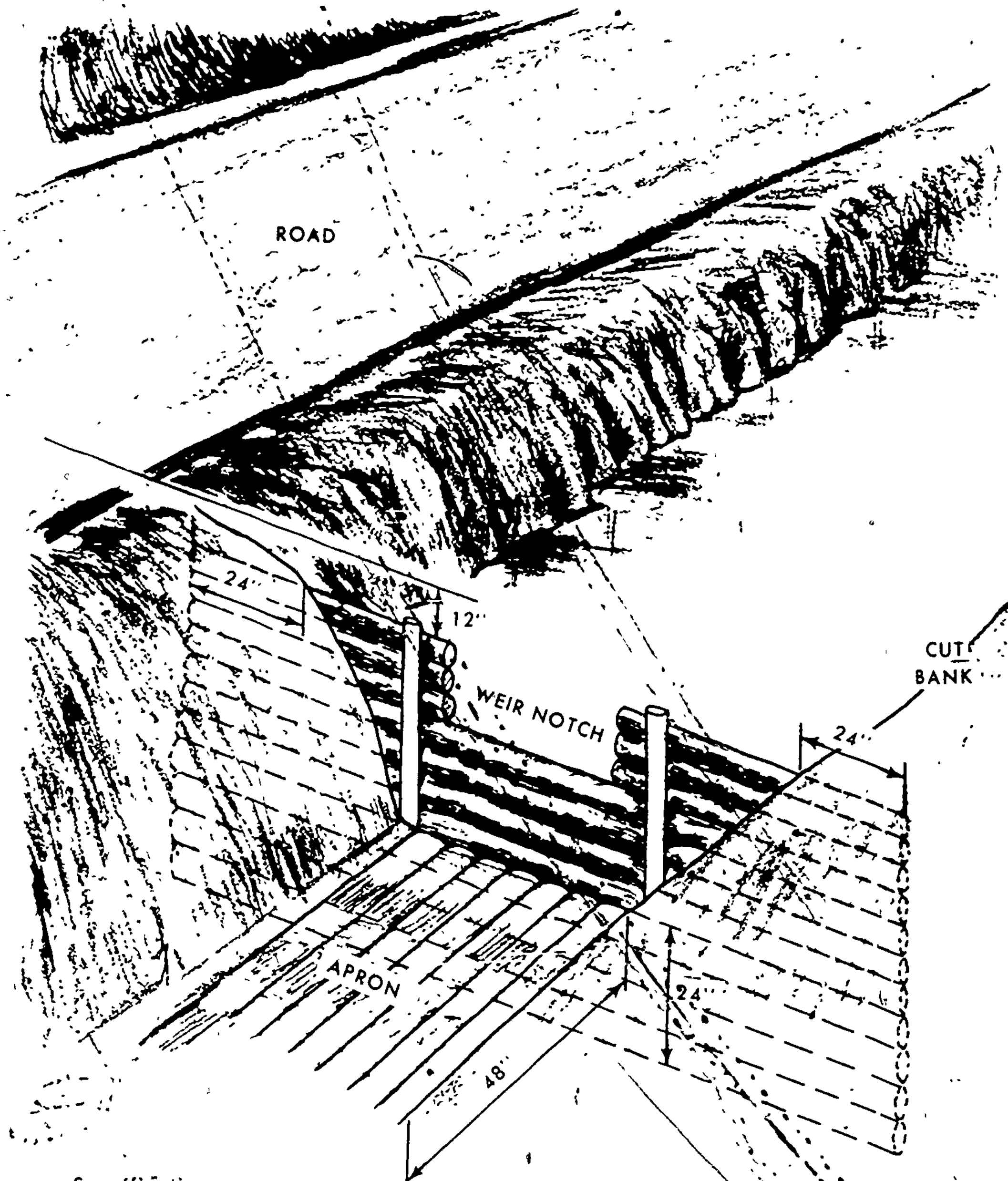
Panel 6-2. Typical Ditch Cross Sections.



Panel 6-3. Typical Shallow "V" Ditch (Unequal Sides) for Military Airfields.



Panel 6-4. Timber Checkdam.



Specifications

Extend into sides and bottom at least 24 inches

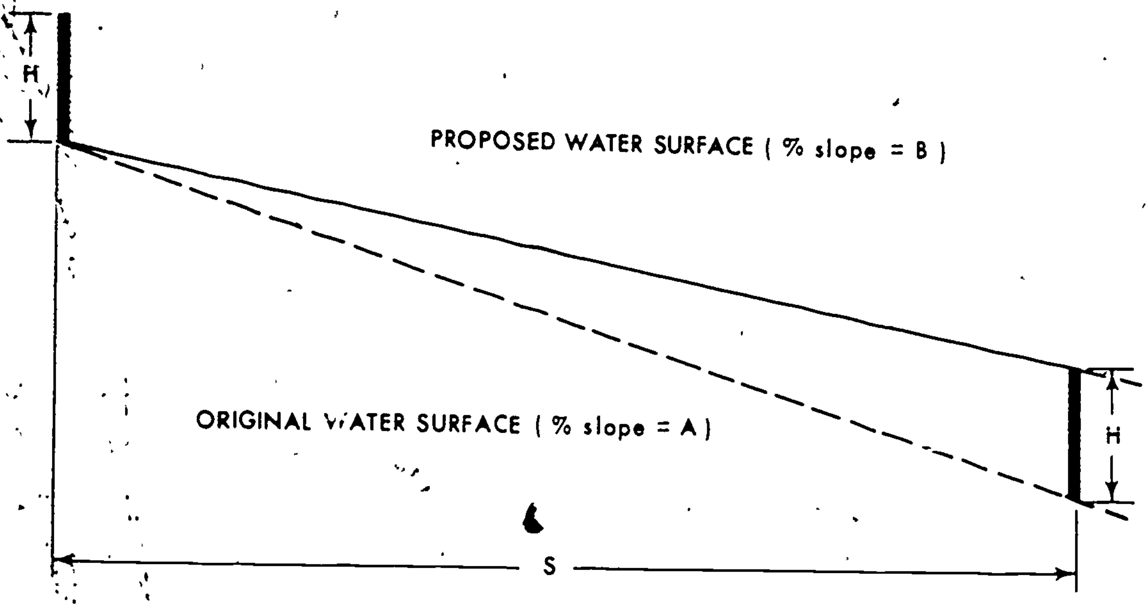
Ditch bank must extend 12 inches or more above top

Aprons should extend downstream approx 3 feet / ft of drop (measured from bottom of weir)

Effective height must be between 12 and 36 inches

Weir notch — $Q = 3LH\frac{3}{2} + \frac{1}{2}H$

Panel 6-5. Checkdam Spacing.



The ideal slope of woter surface is 40 or 50 to 1.

Spacing of checkdams to achieve this objective is determined by the formula:

$$S = \frac{100\,H}{A - B}$$

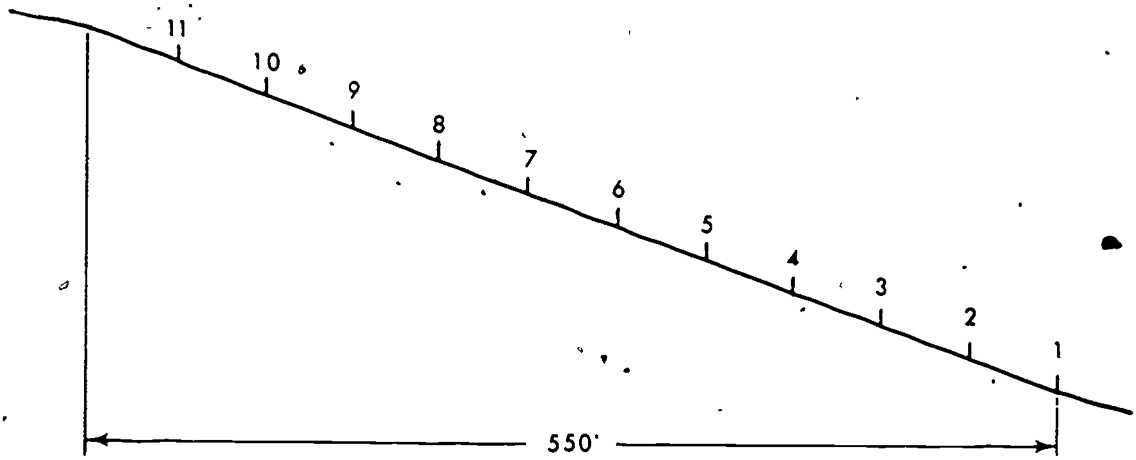
Where :

H = height of checkdam in feet (ditch bottom to bottom of weir notch)

A = percent slope of existing ditch

B = percent slope of desired woter surfoce

Panel 6-6. Method of Determining Number of Checkdams Required.



$$N = \frac{\text{length of ditch}}{\text{spacing}}$$

Solution frame 6—21:

$$S = \frac{100 \times 1}{4 - 2} = \frac{100}{2} = 50 \text{ ft}$$

$$N = \frac{550}{50} = 11$$

Proof:

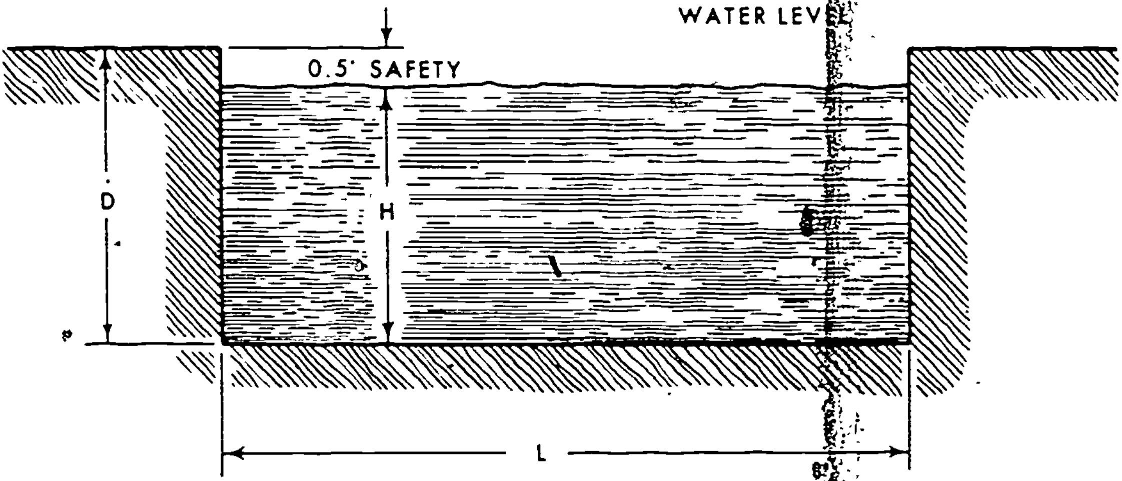
Difference in elevation = 550 × .04 = 22 ft, total drop

The 11 checkdams will take up 11 ft

Then: 22 — 11 = 11 ft, and

$\frac{11}{550} \times 100 = 2\%$, final effective slope of water surface.

Panel 6-7. Size of Weir Notch



Size of slot may be derived from the formula:

$$Q = CLH^{3/2}$$

Where:

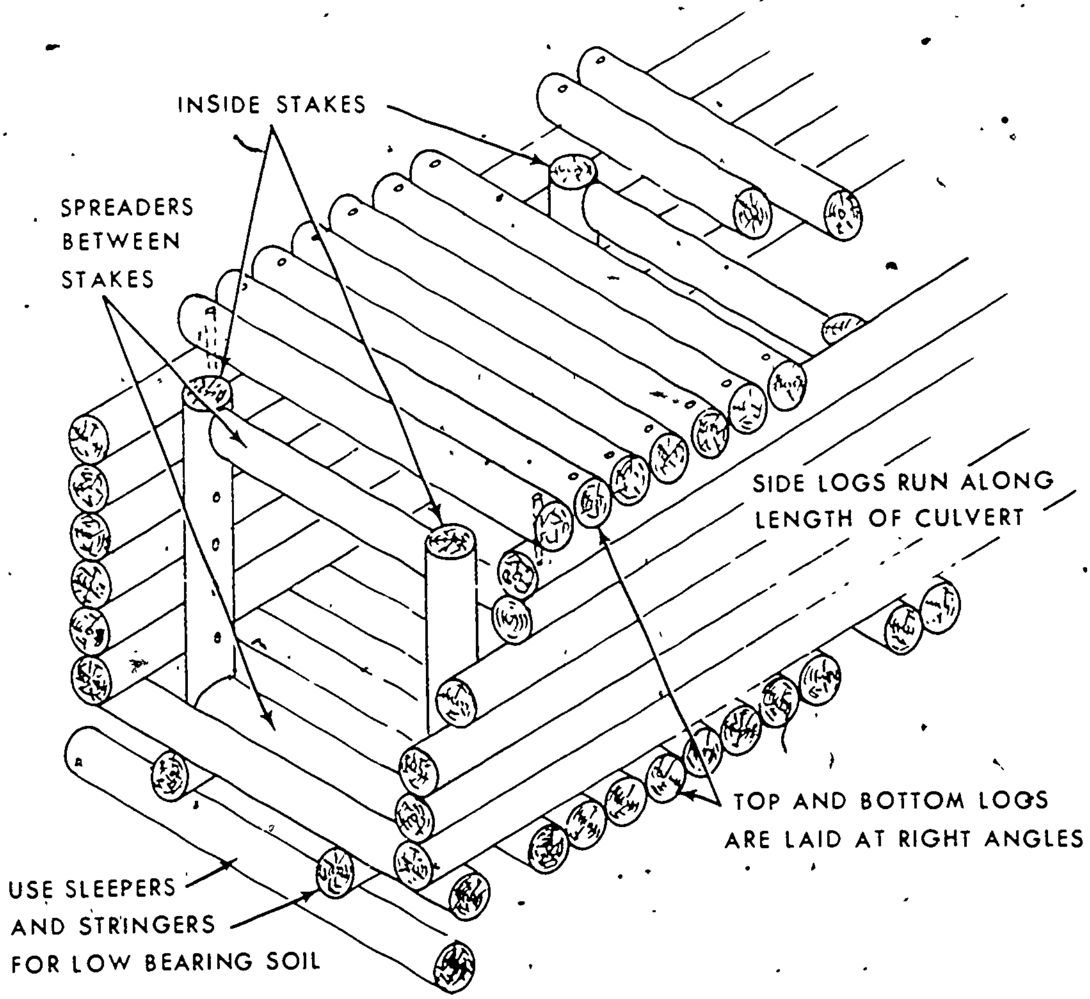
Q = peak rate of runoff through ditch in cfs
C = 3 (constant)
L = length of notch in feet
H = depth of flow through notch in feet.

Then:

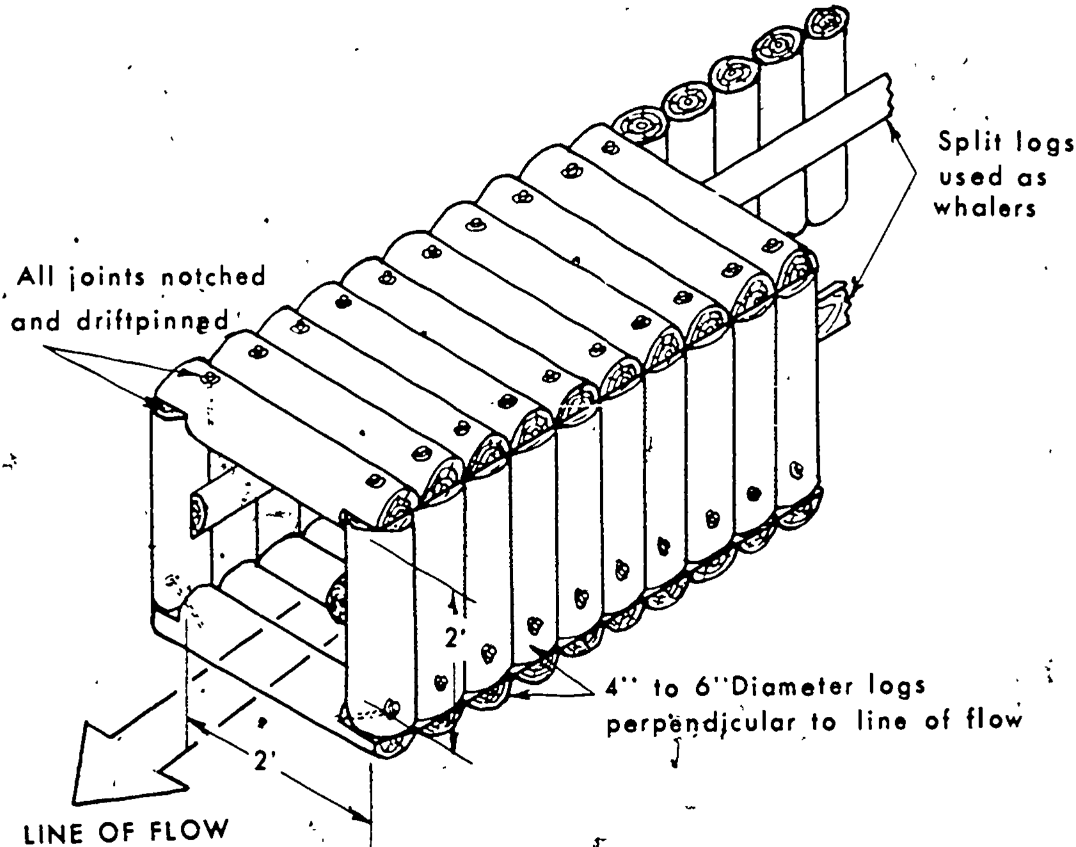
$$L = \frac{Q}{CH^{3/2}}$$ and

$$H = \left[\frac{Q}{CL}\right]^{2/3}$$

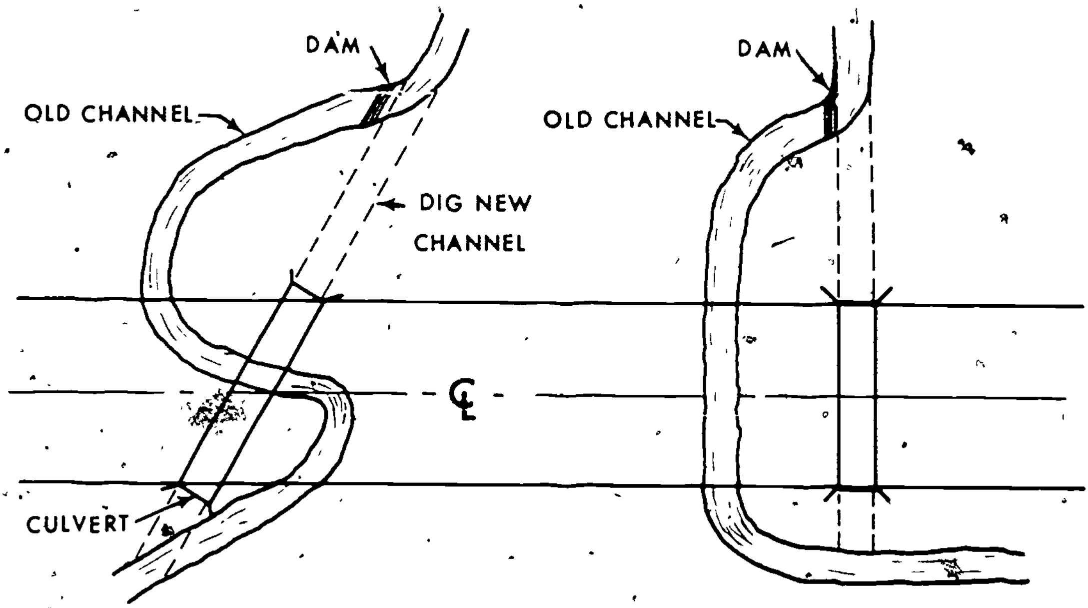
Panel 6-8. Standard Log Box Culvert.



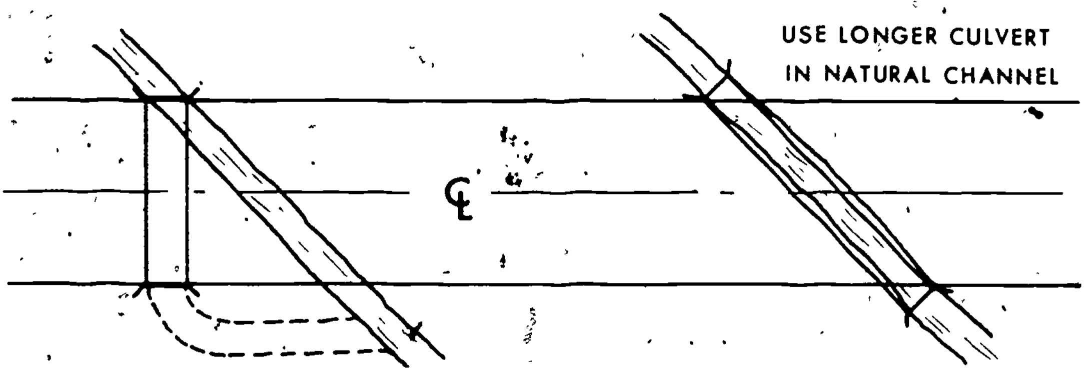
Panel 6-9. Alternate Log Box Culvert.



Panel 6-10. Alinement of Culverts.



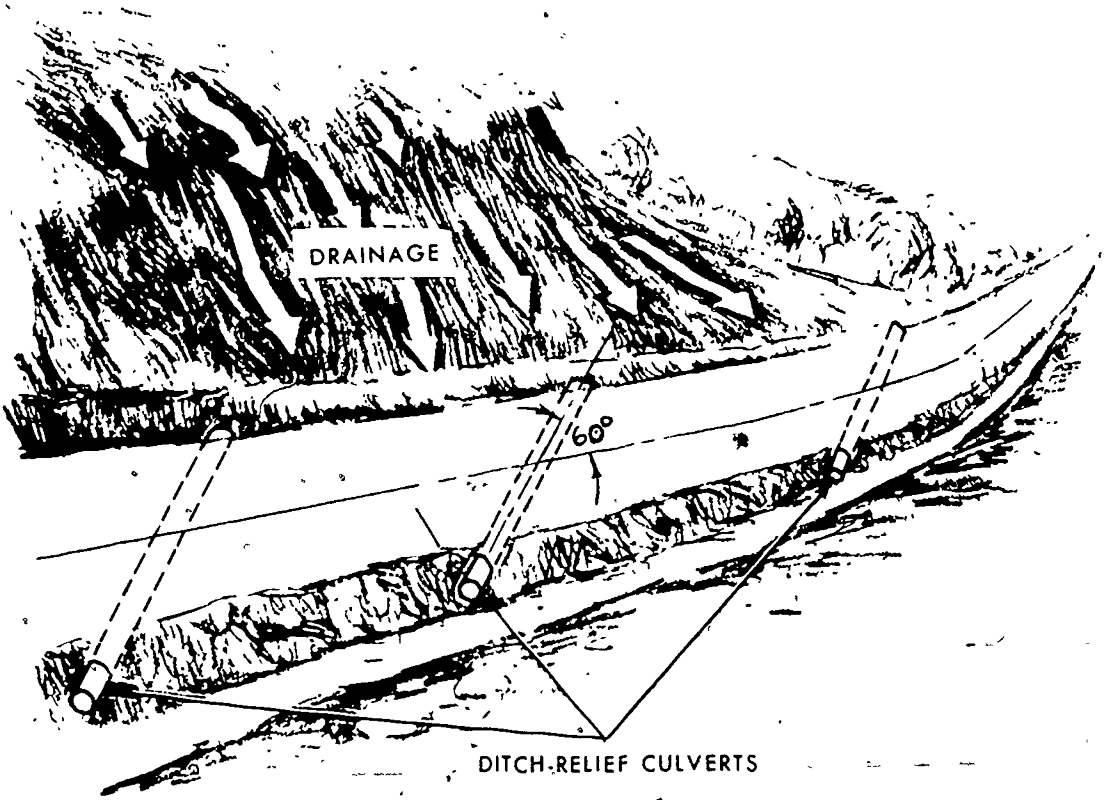
SHIFTING CHANNEL TO PROPER ALINEMENT

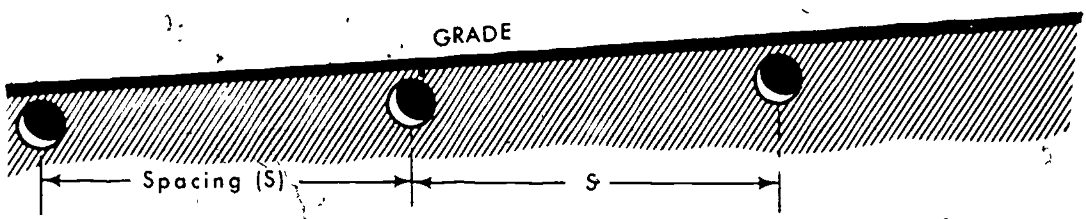


BAD ALINEMENT

GOOD ALINEMENT

Panel 6-11. Ditch-Relief Culverts.

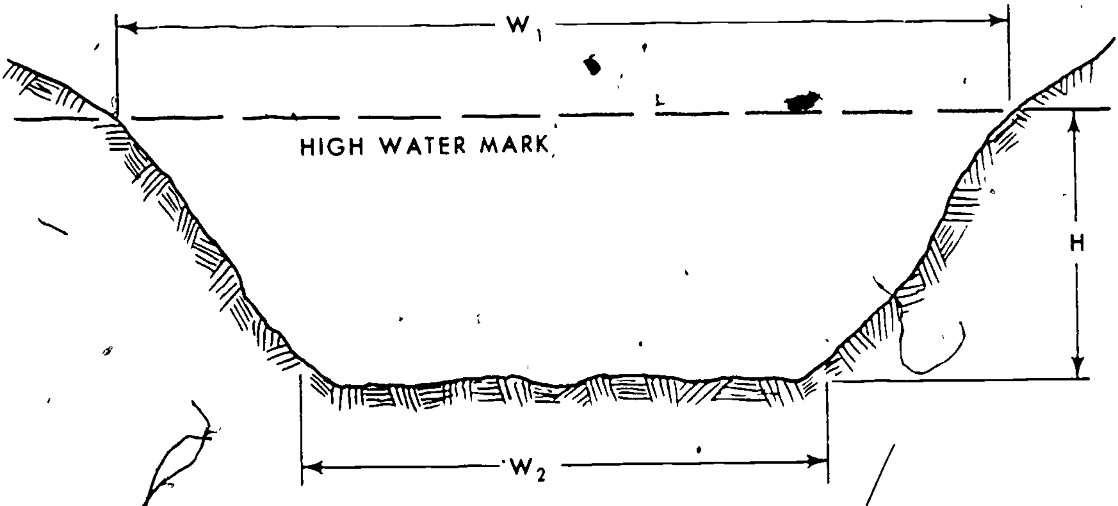




FOR: 5% grades S = about 500 feet

8% grades S = about 300 feet

Panel 6-12. Typical Stream Cross Section.



FORMULAS:

$$\text{Area of channel} = \frac{W_1 + W_2}{2} \times H$$

$$\text{A (design area of culvert)} = \frac{W_1 + W_2}{2} \times H + 100\% \text{ (safety factor)}$$

Where:

W_1 = width of channel at the high water mark

W_2 = width of channel at the bottom of the streambed

H = vertical distance in feet from the bottom of the streambed to the high water mark

Example:

Given — W_1 = 5'

W_2 = 3'

H = 4'

Find design area of culvert:

$$A = \frac{5 + 3}{2} \times 4 + 100\%$$

$$= 4 \times 4 + 100\% = \qquad \text{sq ft}$$

Panel 6-13. Talbot's Formula.

Talbot's formula states that the design area for culverts is equal to the fourth root of the cube of the drainage area in acres, multiplied by a coefficient of runoff or:

$$A = C \sqrt[4]{D^3}$$

In which,

A = area of waterway opening in square feet.

C = a coefficient that depends upon the slope, shape, and general character of the area to be drained.

D = drainage area in acres.

The value of the coefficient C is influenced by the shape of the drainage area, the side slopes and the length of the valleys, and by the general character and culture of the ground. All of these factors affect the rate of runoff. Therefore the engineer must adjust the value of C to suit each case. The value of C should be increased as the lengths of valleys decrease in proportion to their widths, and vice versa. As side slopes steepen, C should be increased. Heavy scrub-growth would decrease the value of C as compared with cultivated farm land, whereas rock or barren slopes would increase the value of C. A value of 1.0 is satisfactory for moderately mountainous terrain, or for reasonably steep barren areas with abrupt slopes up to 10 percent. Normal values for C are as follows:

C = 0.2 for flat areas not affected by accumulated snow and where the length of valley drained is several times the width.

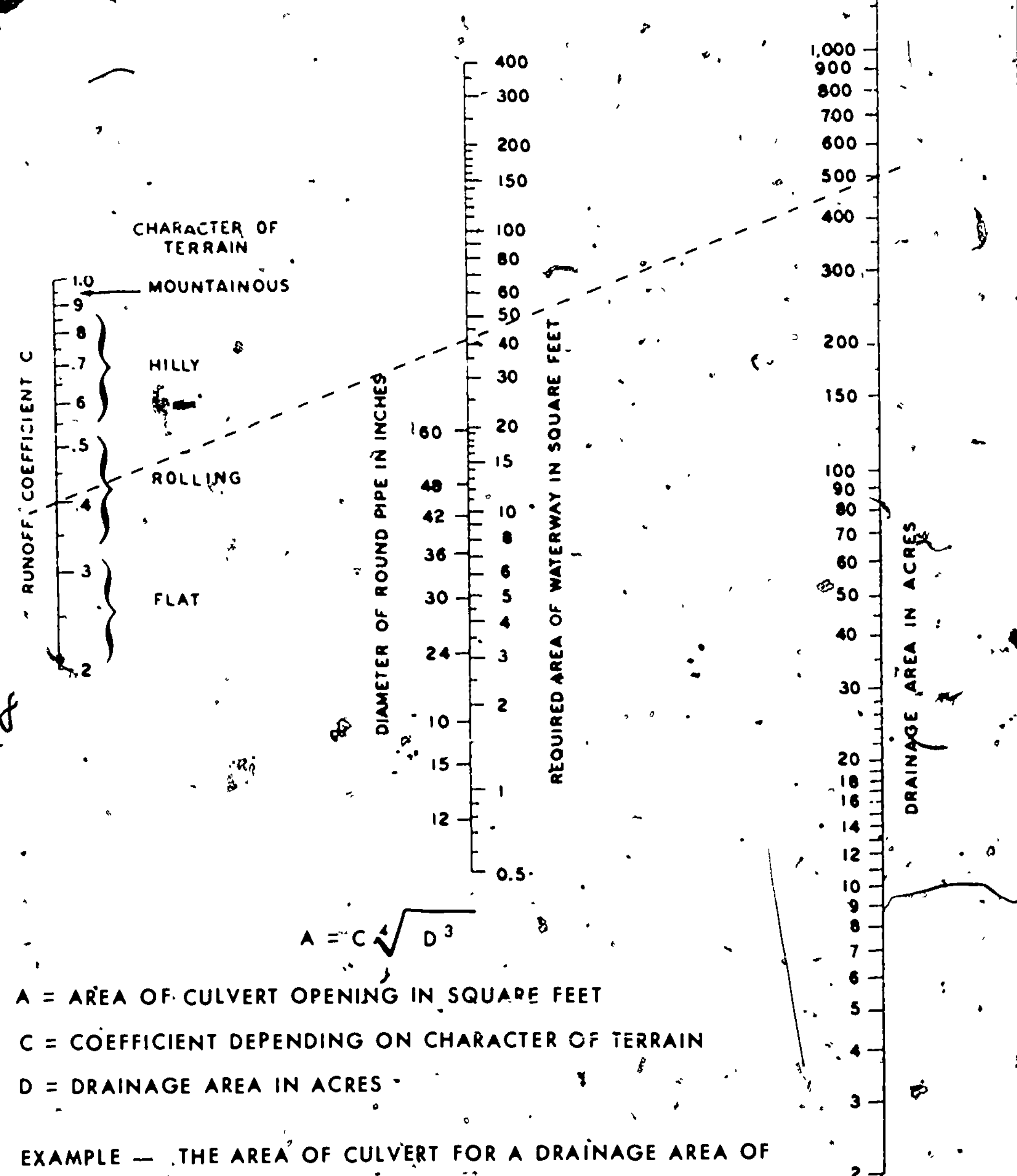
C = 0.35 for gently rolling farm land where the length of valley is about 3 or 4 times the width.

C = 0.7 for rough hilly area having moderate slopes.

C = 1.0 for steep, barren areas having abrupt slopes, and for moderately mountainous areas.

Panel 6-14. Talbot's Formula Nomograph.

By placing a straightedge across the nomograph with its ends connecting the estimated value for C and the proper drainage area in acres, the required area of waterway in square feet can be read directly. This is the correct area required for the culvert and no safety factor need be added.



$$A = C \sqrt[4]{D^3}$$

A = AREA OF CULVERT OPENING IN SQUARE FEET

C = COEFFICIENT DEPENDING ON CHARACTER OF TERRAIN

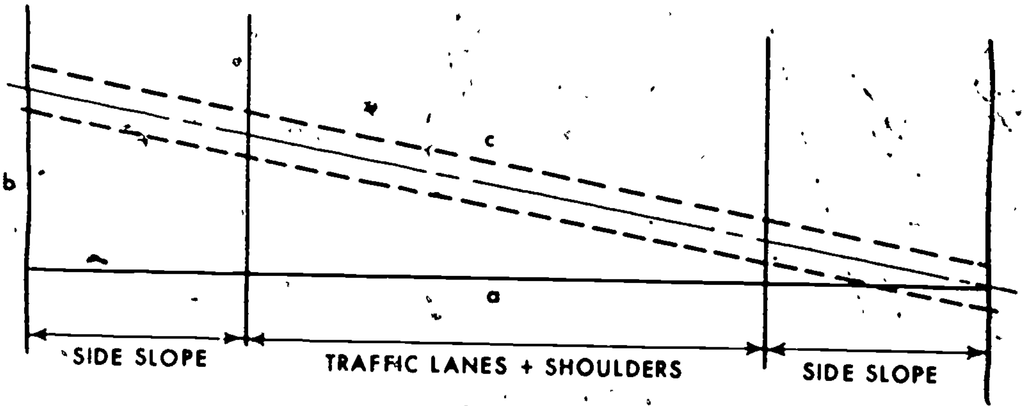
D = DRAINAGE AREA IN ACRES

EXAMPLE — THE AREA OF CULVERT FOR A DRAINAGE AREA OF 500 ACRES IN GENTLY ROLLING TERRAIN (COEFFICIENT "C"=0.4) IS 42 SQUARE FEET (SEE DASHED LINE, ABOVE).

Panel 6-15. Pipe Sizes and End Area.

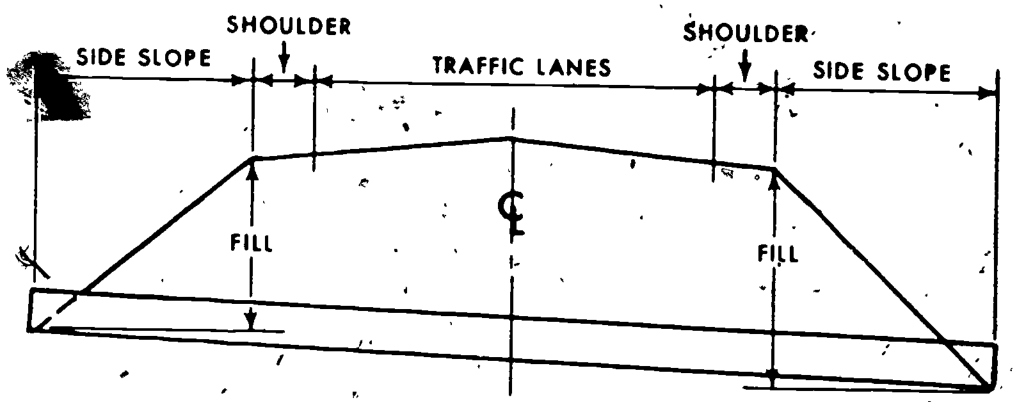
Diameter in inches	Waterway area (sq ft)
8	0.35
10	0.55
12	0.79
15	1.23
18	1.77
21	2.41
24	3.14
30	4.91
36	7.07
42	9.62
48	12.57
54	15.90
60	19.64
66	23.76
72	28.27
78	33.18
84	38.49

Panel 6-16. Culvert Length.



PLAN

(1) Diagram for culvert placed @ angle less than 90° to centerline of road. Length of culvert (c) may be measured; or solve for (a) as in diagram (2) below, measure line (b): then, $c = \sqrt{a^2 + b^2}$

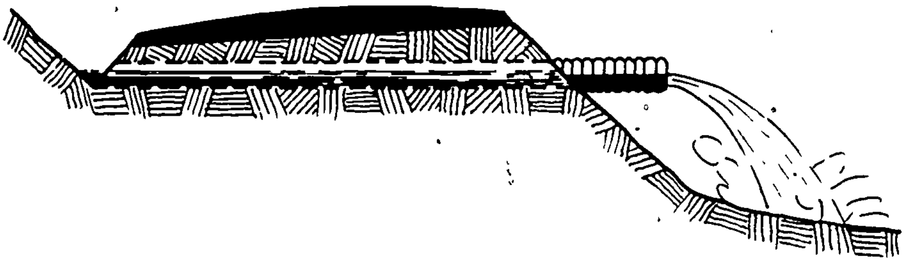


SECTION

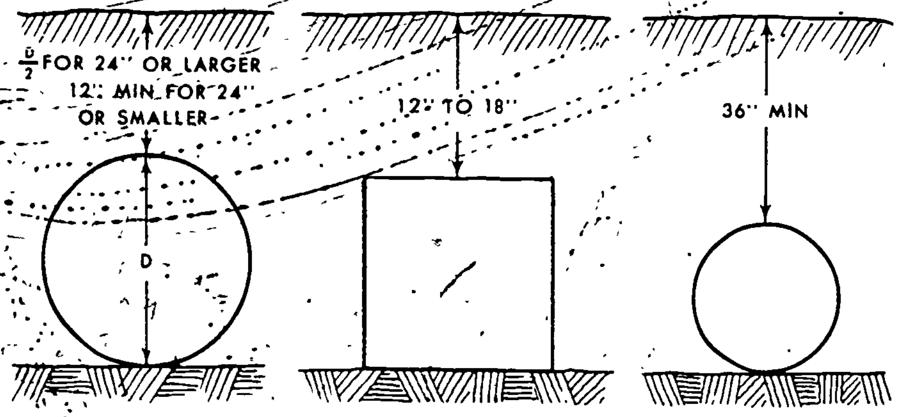
(2) Diagram for culvert placed @ 90° perpendicular to centerline of road. Minimum length of culvert = traffic lanes + shoulders + horizontal side slope distances (@ 90° perpendicular to)

Given : Standard two-lane road
Fill = 6 feet
Side slope = 2 : 1
Find length of culvert w/headwalls
Solution :
2-lane road = 23 ft (Panel 1—2)
Shoulders = 2 x 4 = 8 ft (Panel 1 — 2)
Slopes = (2x6) + (2x6) = 24 ft
23 + 8 + 24 = 55 ft
Add 2 ft, if wingwalls are not used.

Panel 6-17. Culvert Extended Beyond Fill to Prevent Scouring.



Panel 6-18. Culvert Cover Requirements.



FOR PIPE CULVERTS——

Maximum size pipe allowable is based on the formula,

$$D_{max} = \frac{2}{3} F \text{(fill depth in inches)}$$

Given: F = 6.25 feet

Find: Maximum allowable size pipe and minimum cover

$$D = \frac{2}{3}F = \frac{2}{3}(6.25 \times 12) = 50 \text{ inches}$$

Use 48-inch pipe*

Cover $= \frac{D}{2} = \frac{48}{2} =$ ___ inch minimum

* If calculations for D (the diameter) give a nonstandard size pipe, drop back to the next smaller standard size pipe (panel 6—15). Never go above the maximum allowable pipe size.

Panel 6-19. Pipe Cover Requirements for Airfields.

PIPE COVER REQUIREMENTS FOR AIRFIELDS (IN FEET)

(Data Prepared by the U.S. Engineers, Office of the Chief, of Engineers)

TYPE OF PIPE	30,000 LB PLANE						80,000 LB PLANE						120,000 LB PLANE						300,000 LB PLANE					
(Pipe Diameter in Inches)	6	12	24	36	48	60	6	12	24	36	48	60	6	12	24	36	48	60	6	12	24	36	48	60
Clay Sewer Pipe	15	30	30	35			30						40						70					
Clay Culvert Pipe (AASHO)		15	15	20				30	35	35				35	45	45								
Concrete Sewer Pipe	1.5	25	30				30	40					40						60					
Reinforced Concrete Sewer Pipe		20	30	35	4.0	40		35						45										
Reinforced Concrete Culvert Pipe		1.5	20	20	20	20		25	30	35	35	35		30	40	45				40	60	70	90	100
Reinforced Concrete Culvert Pipe (Extra Strength)			10	1.0	10	10			25	25	25	25			30	35	35	35		4.0	50	60	60	70
Corrugated Metal Pipe—18 Gage	10						15	20					20						30					
Corrugated Metal Pipe—16 Gage		1.0	15				10	2.0	30				1.5	2.5	40				20	30	60			
Corrugated Metal Pipe—14 Gage			10	20				15	25	35				20	30	40				25	50	70		
Corrugated Metal Pipe—12 Gage				10	2.0				15	25	35			15	25	35	40				40	60	70	
Corrugated Metal Pipe—10 Gage					10	1.5				20	25	3.0			20	30	35	40			3.5	5.5	65	70
Corrugated Metal Pipe—8 Gage						1.0					20	25				25	30	35			30	5.0	60	65

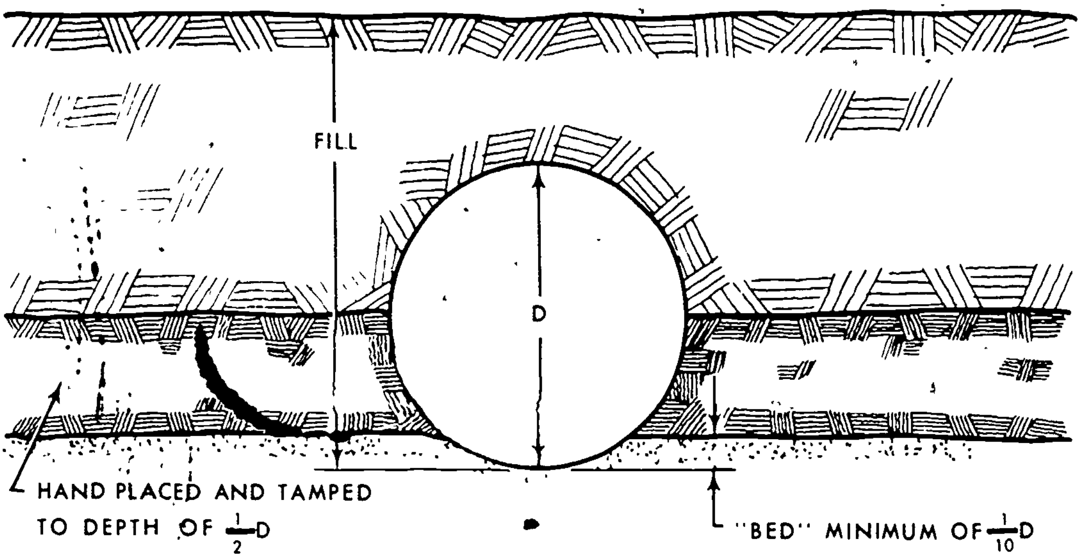
NOTES:

1. Pipe to conform to ASTM Specifications except as noted. Pipe produced by certain manufacturers exceeds strength established by ASTM standards. When proof of extra strength is submitted the minimum cover may be varied accordingly.

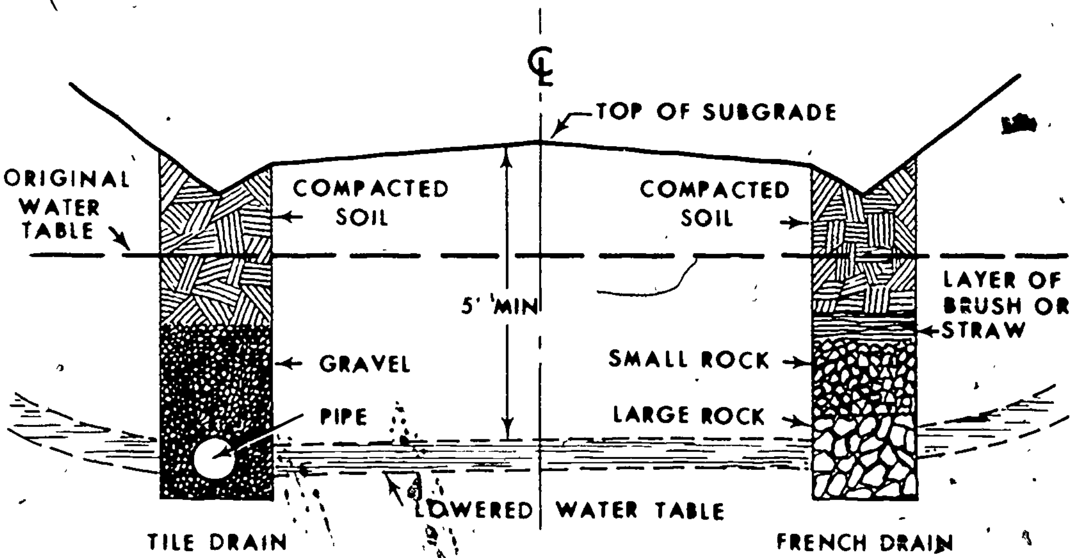
2. Cover for pipes within landing or taxiway strips or similar traffic areas shall be provided in accordance with above table except as provided for rigid pavements in Note 3 below.

3. Pipe placed under concrete airfield pavements shall have a minimum cover measured below the slab of 1.0 foot for plane loads up to and including 120,000 lbs and 2.0 feet for 300,000 lb plane loads, except that minimum cover below thickened edges may be reduced to 0.5 foot for 120,000 lb plane loads or less, and to 1.0 foot for 300,000 lb plane loads.

Panel 6-20. Culvert Foundation.



Panel 6-21. Subsurface Drains.



LESSON 6

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

1. When is drainage construction begun with reference to the construction sequence? Why? (frame 6-4)

2. What are the maximum and minimum slopes recommended and why are surfaces designed with gentle slopes? (frames 6-8, 6-16)

3. The motorized grader can be used to construct any of the three types of drainage ditches. Give the three types and tell what they are best suited for. (frame 6-14)

4. Give the purpose of checkdams and tell how protection against erosion and scouring is provided around checkdams. (frame 6-17, 6-18)

5. Given the following information on a checkdam being built:

H is equal to minimum value allowed

B is equal to minimum value allowed

A is equal to 7% slope

Determine the spacing of checkdams according to the formula for spacing (frame 6-19 and panels 6-4, 6-5)

6. Determine the number of checkdams required in a 600 foot ditch from 4 percent to 2 percent. Each drop is 2 feet high. (frame 6-21, panel 6-6)

7. Describe the purpose of a culvert. (frame 6-24)

8. Support your choice of the following culverts as being the easiest to construct. (frame 6-25)

a. log-box

b. timber-box

c. oil drum

d. CMP

9. What material is ideal for use for expedient culverts? (frame 6-30)

10. Although the first principle in placing culverts is to continue the original direction of flow if possible, what method should be employed in providing cross drainage for a meandering stream? (frames 6-32, 6-34)

11. What should be the spacing, in feet, of ditch-relief culverts on an 8-percent grade? (frame 6-35)

12. Using the reconnaissance method, what would be the design area (sq ft) of a culvert which has a channel width of 8 feet at the high water mark, 6 feet at the bottom of the stream bed, and the distance from the channel bed to high water mark is 6 feet? (frame 6-42 and panel 6-12)

13. If a culvert is to provide for a drainage area of 15 acres of gently rolling farm land, what diameter of pipe (inches) should be used? Use Talbot's formula nomograph assuming C = 0.4. (frame 6-44 and panel 6-14)

14. If a culvert requires a design area of 25 square feet, how many 48-inch-diameter pipes would be required? (frame 6-46 and panel 6-15)

15. If the fill section of a roadway is 7.8 feet, what would be the maximum size pipe (inches) which might be used to construct a culvert? (frame 6-51 and panel 6-18)

16. What is the minimum cover requirements (feet) for a CMP culvert of 16 gage, 24 inches in diameter, designed to carry a 120,000-pound plane? (frame 6-53 and panel 6-19)

17. To what depth in inches should the fill around a 36 inch-diameter CMP culvert be well tamped? (frame 6-58 and panel 6-20)

18. Describe the purpose of subsurface drainage. (frame 6-60)

19. What is the minimum distance in feet that a military road or airfield should be located above the ground water table? (frame 6-61)

20. Under normal circumstances, a trapezoidal ditch would not be suitable to provide for subsurface drainage. Under what conditions can deep open ditches be used for subsurface drainage? (frame 6-67)

21. Explain the difference between the French drain and the tile drain. (frame 6-72)

LESSON 7

EARTHWORK OPERATIONS AND EXPEDIENT SURFACES

CREDIT HOURS ________ 1

TEXT ASSIGNMENT ______ Attached Memorandum.

LESSON OBJECTIVES

Upon completion of this lesson, you will, in following subject areas, be able to:

1. **Typical construction tasks** — Discuss the logical sequence for scheduling; define key words in scheduling; explain the use of the dozer for ground preparation and construction; and finally describe the components of a road and airfield.
2. **Road expedients** — Discuss the classification of road expedients according to terrain and construction effort; discuss construction of corduroy roads, chespaling, portable metal landing mats, the army track, tread roads, and snow and ice expedients.
3. **Airfield portable surfaces** — Discuss airfield portable surfaces to include the two classes (landing mat and nylon membrane), their description and use, and describe briefly the use of dust palliatives and their limitations.

CONTENTS

Set 1. Typical Construction Tasks.

FRAME 7-1.

A road or airfield construction project is broken down into basic construction tasks which are performed in logical phases or sequence. After one task of the project, such as the clearing of trees and brush, has been completed on a certain area, the second construction task of stripping the area is begun. At the same time, the first task of clearing would be started in another area. Thus, time and effort can be saved by performing several types of construction tasks simultaneously. The simultaneous scheduling of construction ________________ in logical ________________ contributes to the efficient completion of a construction project.

(subbase) (depth) (7-15)

FRAME 7-16.

As previously discussed, compaction is required to obtain a stable soil foundation. Heavy pneumatic-tired rollers are preferred for ________________ the ________________, but final shaping is done with the grader.

(stringers) (substantial) (7-30)

FRAME 7-31.

The third type of corduroy — heavy (panel 7-4) — requires the use of sleepers. These are heavy logs 10 to 12 inches in diameter and long enough to carry the entire road and are placed at right angles to the centerline on 4-foot centers. Sleepers give added __________ and stability to the roadway. The corduroy with stringers is constructed on top of the sleepers.

(army track) (smooth) (7-45)

FRAME 7-46.

Another expedient is the tread road. Tread roads are made by preparing two narrow parallel treadways of select material for vehicular wheels to use over otherwise impassable ground. The material used may be anything from palm leaves to 4-inch planks with a consequent wide variation in the capacity and durability of the road. Roads made by preparing two narrow parallel treadways of select material are called __________ roads.

(tasks) (phases) (7-1)

FRAME 7-2.

A step or particular type operation in a construction project is known as a (1) ______________. When the task is performed would be its (2) ______________.

(compacting) (subbase) (7-16)

FRAME 7-17.

Up to this point, military roads, airfields, and railroads are similar in construction. Roads and airfields now require a **base course** and wearing surface while railroads are completed by the placement of ties, rails, and ballast on the subgrade. In road and airfield construction, the ______________ ______________ is laid over the ______________ or ______________.

(strength) (7-31)

FRAME 7-32.

Portable corduroy mats made by wiring together 4-inch logs can be prefabricated and put down quickly when needed. These ______________ corduroy mats have the advantage in that they may be ______________.

(tread) (7-46)

FRAME 7-47.

Because of the wide variance of materials from which they can be constructed, tread roads can be either "hasty" or "heavy" expedients. Tread type construction is better adapted to muddy terrain than to sandy, though a heavy treadway can be used in either type situation. Tread roads can either be ______________ or ______________ expedients.

(1) task (2) phase (7-2)

FRAME 7-3.

Specific construction tasks are common to road, airfield, and railroad projects. These tasks include – clearing and grubbing, stripping, ditching (drainage), cut and fill (earthwork), compaction, preparation of subbase and base course, and surfacing. The ________________ completion of projects depends on the proper ________________ of construction tasks.

(base course) (subbase) (subgrade) (7-17)

FRAME 7-18.

Base course construction includes the placing and compaction of controlled lifts of blended aggregate. The material used for a (1) ________________ ________________ is generally well graded gravel or crushed rock. If necessary, the materials may be (2) ________________ on the job by using a grader. Best compaction is obtained from pneumatic-tired rollers with final rolling made by three-wheel rollers. As with subgrades, high spots are removed and final shaping is done with the (3) ________________.

(portable) (prefabricated) (7-32)

FRAME 7-33.

Diagonal corduroy, with decking placed at an angle of about 45° to the centerline, is a modified construction applicable to any of the three common types of corduroy. Putting the decking at an angle decreases the impact load, since each log supports only one wheel at a time and there is longitudinal as well as lateral weight distribution. Diagonal corduroy is preferred for heavy traffic. For ________________ traffic, ________________ corduroy is used to reduce ________________ loads.

(hasty) (heavy) (7-47)

FRAME 7-48.

The most important single type of tread road is the plank tread road (panel 7-8). Sleepers 12 to 16 feet long are first laid perpendicular to the centerline, on 3-to-4-foot centers depending on the loads to be carried and subgrade conditions. Then place 4 x 10-inch planks parallel to the traffic to form 2 treads, about 36 inches apart. If finished timber is not available, use logs as sleepers. The ________________ ________________ ________________ is the most important type of tread road. When securely spiked together, a plank tread road is a very durable "heavy" expedient.

(efficient) (scheduling) (7-3)

FRAME 7-4.

Clearing includes the removal of brush and trees from the construction site. Clearing should start at the point of disposal and fan outward so that trees and brush can be pushed over a cleared area. If logs are cut from felled trees, this should be done in the disposal area to avoid interference with the clearing operation. (1) ________________ should begin at the point of (2) ________________ and (3) ________________ ________________ for the efficient removal of trees and brush from an area.

---

(1) base course (2) blended (3) grader (7-18)

FRAME 7-19.

The final construction task is that of surface preparation. For military roads the top of the base course will often be used as the wearing surface. Fine material will be spread, watered, and rolled with a steel wheeled roller to give the road a smooth water repellant ____________________. To provide a longer lasting road a bituminous surface may be used.

(1) heavy (2) diagonal (3) impact (7-33)

FRAME 7-34.

Chespaling, a "hasty" expedient used in either mud or sand, is made from small green saplings preferably about $1\frac{1}{2}$ inches in diameter, and $6\frac{1}{2}$ feet long, wired together to form about a 12-foot-long mat (panel 7-5). These mats are often rolled into bundles and carried on each wheeled vehicle, then used when necessary to cross sandy terrain or to get out of mud. ________ is a hasty expedient which can be used satisfactorily in either ________ or ________.

(plank) (tread) (road) (7-48)

FRAME 7-49.

Now let us consider expedient roadways for snow and ice conditions. An adverse condition is encountered where snow and ice are so plentiful as to make removal impractical. Here expedient roads can be made out of the snow itself. When the road is laid out, more emphasis must be placed on making grades and curves as gentle as possible. Then the snow is compacted into a hard mass capable of supporting the weight of vehicles. A harder surface can be made by pouring water on the compacted snow and allowing it to freeze. When snow and ice cannot be removed, a road can be made by ________ the snow and making the ________ and ________ as gentle as possible.

(1) clearing (2) disposal (3) fan outward (7-4)

FRAME 7-5.

Two types of equipment are used in (1) ________________ operations. The crawler dozer is the best piece of equipment when large trees or steep slopes are involved. Wheeled dozers do well in light clearing operations. In a heavy stand of large timber (2) ________________ ________________ would be used; (3) ________________ ________________ would be inefficient.

(surface) (7-19)

FRAME 7-20.

Except for forward Army runways, military airfields are almost always surfaced. After the ________________ ________________ has been prepared a portable landing mat or a bituminous ________________ is added.

(chespaling) (mud) (sand) (7-34)

FRAME 7-35.

Chespaling mats may be constructed from dimensioned timbers and wired together to resemble a picket fence. A variation, slightly more effective for crossing sand, is made by attaching chicken wire netting to the bottom of the mats. Attaching ______________ ______________ ______________ to the bottom of chespaling mats, makes them more effective in ______________.

(compacting) (curves) (grades) (7-49)

FRAME 7-50.

Frozen lakes or streams can be used to move traffic. However, the route must be first carefully reconnoitered for quality of ice, thickness, cracks, and shore conditions. The load bearing capacity can be determined either by an actual test or by consulting tables, such as panel 7-9. Ice 12 to 15 inches thick will safely support ______________ ton vehicles spaced ______________ feet apart.

(1) clearing (2) crawler dozers (3) wheeled dozers (7-5)

FRAME 7-6.

Grubbing is the removal and disposal of stumps and embedded boulders left in the area after clearing. Crawler dozers are very efficient for removing stumps up to 30 inches in diameter. The removal of stumps after clearing is a ________ task for which the ________ ________ can be used effectively.

Set 2. Road Expedients.

(base course) (surface) (7-20)

FRAME 7-21.

In the theater of operations, orthodox or permanent construction of military roads is often impossible due to the condition of the ground, the tactical situation, or other circumstances and in such cases some expedient means must be employed. In place of orthodox or permanent construction methods, ________ methods must often be used for the construction of military roads.

(chicken wire netting) (sand) (7-35)

FRAME 7-36.

A chespaling road is constructed by laying a double row of mats, each mat having its long axis parallel to the centerline, with a 1-foot overlap at the centerline. The successive mats are then wired together. This type of road must be kept wet to prevent the saplings from becoming brittle and breaking. Chespaling mats should have a 1-foot overlap and should be (1) ________ together. The saplings should also be kept (2) ________________.

Set 3. Airfield Portable Surfaces.

(10) (65) (7-50)

FRAME 7-51.

The use of **portable surfaces** of some kind provides certain advantages in the construction of airfield surfaces. Batching plant erection and the logistical problems encountered when using concrete or bituminous materials usually preclude the extensive use of permanent type surfacing in theater of operations airfield construction. The time required to surface a runway with ____________ ________________ is far less than with a concrete or bituminous surface.

(grubbing) (crawler dozer) (7-6)

FRAME 7-7.

Stripping, another task, consists of removing the organic material or overburden from the project area. The removal of topsoil would be termed ________.

(expedient) (7-21)

FRAME 7-22.

The choice of the material used is important in securing best and quickest results. With a choice of materials, the principal factors which will determine the type of expedient used will be the time available for construction, desired life of the road, and the type of terrain the road must traverse. On the other hand, the type of material available will be the controlling factor which will determine the ________________ of ________________ selected.

(1) wired (2) wet (7-36)

FRAME 7-37.

An excellent chespaling type expedient for beach roadways, used extensively in the Pacific theater in World War II, is the bamboo mat. These mats are very light and comparatively strong. They are made by splitting 2-inch bamboo rods and weaving them into a mat in a manner similar to rug-weaving. The rods should be soaked before weaving and the mats should be kept moist while in use. For beach roadways the ______________ ______________ is an excellent expedient.

(portable) (surfaces) (7-51)

FRAME 7-52.

Portable surfaces for airfields fall into two principal classes — the **landing mat** and **nylon membrane.** Landing mats are designed to provide a structural load distributing media and wearing surface. Nylon membranes are intended only to protect otherwise structurally adequate surfaces from changing character in wet weather and to eliminate dust. The two principal classes of airfield portable surfaces are ______________ ______________ and ______________ ______________.

(stripping) (7-7)

FRAME 7-8.

The equipment used in stripping are dozers, tractor scrapers, and graders. Dozers are the best choice of equipment when the material is to be moved only a short distance. For longer hauls, the tractor scraper combination is best. For light stripping, the grader can be used. Scrapers are loaded while moving forward to the disposal area. Therefore, in stripping for an airstrip, the tractor scraper would be used for (1) ______________ hauls, the dozer for (2) ______________ hauls. Light stripping could be accomplished by use of the (3) ______________.

(type) (expedient) (7-22)

FRAME 7-23.

In practice, the life of a facility will depend greatly on the time used to build it. Expedient roads can be classified as "hasty" expedients when they are to be built quickly, and last only a short time, and as "heavy" expedients when they require more time to build and last longer when built. The two expedient types classified by design, life, and time required to construct are ______________ and ______________ expedients.

(bamboo mat) (7-37)

FRAME 7-38.

Another type of expedient roadway is the portable metal landing mat (panel 7-6) designed originally for constructing airfields. Since they can be used for sandy beaches as well as airfields, they have become the foremost expedient for crossing ________________ terrain.

(landing mat) (nylon membrane) (7-52)

FRAME 7-53.

Two general categories of landing mats have been established, one for medium duty and one for light duty. Each is capable of sustaining 200 coverages of a 25,000 pound single wheel load with tire pressure of 250 pounds per square inch. The medium duty mat can be placed over a subgrade with a CBR as low as 4, while the ______________ ______________ mat must be placed on a subgrade having a CBR of at least 10.

(1) long (2) short (3) grader (7-8)

FRAME 7-9.

Ditching is the task of providing drainage for a construction site. Ditching operations include the shaping of open drainage gutters and also the excavation of ditches for utilities or closed drainage systems. The ditching operation should start at the lowest elevation which will insure proper drainage on the project. Care should be taken that backfill material in closed trenches is properly compacted. In view of the above, drainage gutters would be started as (1) ________ as possible to properly drain the site. In closed trenches, (2) ________ material should be carefully compacted.

(hasty) (heavy) (7-23)

FRAME 7-24.

Road expedients can be further classified according to a third factor, type of terrain. "Mud expedients" are structurally strong and spread the load over a wide area of the subgrade. "Sand expedients" need not be structurally strong because they confine the ground under them and take advantage of the high bearing capacity of the sand. Mud and sand expedient roads are used according to ________ conditions. Expedient snow and ice routes would also be examples of classification according to terrain.

356

(sandy) (7-38)

FRAME 7-39.

Metal landing mats can be placed directly on the sand to the length and width desired, though membrane underneath the mats greatly improves the job. The smoother and firmer the subgrade, the better the resulting road. The mat is placed so that its long axis is perpendicular to the flow of traffic and each section must overlap the previous one so that the required connections can be accomplished. When using metal landing mats, the subgrade should be made as ________________ and ________________ as possible.

(light duty) (7-53)

FRAME 7-54.

Integral locking lugs provide easy assembly and end connectors prevent the mats from curling up at the ends. Laying rates vary from 243 to 574 sq ft man-hour. The side and end locking devices enable individual mats to be removed for repair or replacement, even in the middle of a completed runway. The side and end ________________ devices provide ease of assembly and ready replacement.

(1) soon (2) backfill (7-9)

FRAME 7-10.

For trenches, the ditching machine is normally used. For harder materials, the back hoe should be used. For cutting and shaping open ditches, the grader and dozer are employed. There are three methods used in ditching: by use of back hoe, the ditching machine, or ________________ and ________________.

(terrain) (7-24)

FRAME 7-25.

There are several types of materials used for expedient roads such as — corduroy, chespaling, metal landing mats, army track, and others. Each type of material has its advantages and disadvantages in a given situation. Therefore, the type of material used must be ________________ to the particular situation. The engineer with ingenuity will discover additional materials and their adaptation for expedient road construction.

358

(smooth) (firm) (7-39)

FRAME 7-40.

Metal landing mats can also be used on mud, but they are not satisfactory on mud when used alone. Mud pumps through the joints and the mat sinks until it becomes ineffective. Experiments have proven that with the use of membrane to prevent the pumping of the mud, a fairly effective expedient can be constructed. Metal landing mats should not be used in ____________ unless some measures are taken to stop the mud from ____________ through the joints.

(locking) (7-54)

FRAME 7-55.

Several nylon membrane surfaces have been developed, but only the T-17 is available in Army supply. The T-17 is a neoprene-coated nylon membrane designed to furnish a dust-and water-proofing capability for landing areas or access roads. ____________ ____________ surfaces provide a ____________ - and ____________ - ____________ capability for landing areas or access roads.

(grader) (dozer) (7-10)

FRAME 7-11.

Cuts and fills are types of earthmoving operations. Both are made as applicable to maintain a correct grade or elevation for road and airfield projects. Insofar as possible, the cutting operation is planned and keyed-in with the filling operation so that these two operations are as nearly balanced as possible. The removal of excess material is by (1) ________________ and the emplacement of additional material is by (2) ________________. Cuts and fills should be as nearly (3) ________________ as possible.

(keyed or suited). (7-25)

FRAME 7-26.

When materials are available, corduroy construction can be used in any theater of operations where a heavy expedient road is needed over muddy terrain. A corduroy road can be classified both as a ____________ and ____________ expedient.

360

(1) mud (2) pumping (7-40)

FRAME 7-41.

A second layer of the steel mat, laid as a treadway over the initial layer, will further increase the effectiveness of this expedient. In either case, the foundation should be as smooth as possible. A second layer of metal landing mat, used as a ________________, will increase its effectiveness as a road surface.

(nylon membrane) (dust) (water-proofing) (7-55)

FRAME 7-56.

The T-17 membrane is furnished as Membrane Set, Runway Surfacing, and Membrane Set, Taxiway Surfacing. Panels furnished for runway surfacing are 66 feet wide and 100 feet long. Panels furnished for ________________ surfacing are 36 feet wide and 100 feet long.

361

(1) cut (2) fill (3) balanced (7-11)

FRAME 7-12.

As we have seen when discussing stripping, dozers can be used in earthmoving if the spoil is to be moved a (1) ________________ distance. Scrapers are used when a large quantity of material must be moved, and where the haul distance to the stockpile, fill, or disposal point is beyond the economical range of (2) ________________. Panel 7-1 shows the method of cycling enabling the equipment to cut and spread in both directions.

(heavy) (terrain) (7-26)

FRAME 7-27.

There are three types of corduroy construction: standard corduroy, corduroy with stringers, and heavy corduroy. The most frequently constructed __________ is the standard type.

362

(treadway) (7-41)

FRAME 7-42.

One layer of the mat would constitute a "hasty" expedient quick to lay and not durable enough to last long, but a "heavy" expedient can be constructed simply by using several layers, best laid over a prepared base. Metal landing mats can be used to make either ______________ or ______________ expedients.

(taxiway) (7-56)

FRAME 7-57.

The T-17 membrane can be placed on unprepared subgrade, but will offer better service if the topsoil is removed to provide base stability and alinement. No special skill is required for emplacement. A ditch is cut along each side of a runway or road, the panel is then stretched across and anchored by backfilling the ditch. Rolls are laid longitudinally. The panels are overlapped and bonded by an adhesive prepared for neoprene-coated materials. For best results ________ should be __________________ to provide a smooth subgrade.

363

(1) short (2) dozers (7-12)

FRAME 7-13.

Compaction is the artificial densification of a soil mass (fill, subgrade, or base course) without appreciable change in moisture content. After loose material has been spread, it must be compacted to eliminate voids and attain bearing strength thus precluding settlement. The moisture content of the soil being compacted must be carefully controlled. The process of artificial ______________ is called ______________.

(corduroy) (7-27)

FRAME 7-28.

The standard type corduroy (panel 7-2) requires the placing of 6-to 8-inch-diameter logs about 13 feet long adjacent to each other (butt to tip). Along the edges of the roadway thus formed, 6-inch-diameter logs are placed as guardrails (curbs) and drift-pinned in place. The dimensions of the logs used in a standard type corduroy roadway are ______________ to ______________ inches in diameter and about ______________ feet long. Pickets about 4 feet long driven into the ground at regular intervals hold the roadway in place.

364

(hasty) (heavy) (7-42)

FRAME 7-43.

One difficulty encountered in using metal landing mats is their tendency to curl up at edges. This can be overcome by making an excavation at the edges of the road about one foot deep with a three to one slope on the side of the excavation nearest the road. The mats are bent to fit the trench, placed in position and the excavation back-filled over them. Another method of securing the edges is to use a curb as shown in panel 7-6. Metal landing mats will tend to ______________ up at the ______________ and measures should be taken to correct this difficulty.

(topsoil) (removed) (7-57)

FRAME 7-58.

Another method of eliminating dust from runways, taxiways, hardstands, and warmup aprons is by the use of dust palliatives. Oil and vegetation can be used successfully as dust palliatives. However, these cannot be used on the present jet based fields because heat and jet blast would set them on fire and displace them. (1) ______________ is extremely harmful to airplane engines. Oil and vegetation palliatives can only be used on (2) ______________-______________ airfields.

365

(densification) (compaction) (7-13)

FRAME 7-14.

Sheepsfoot and pneumatic-tired rollers are generally used to compact embankments (fills) below the subgrade. Regardless of the equipment used, it is necessary to place the fill in thin layers (6 to 9 inches) to insure uniform (1) ________________ throughout the mass, while at the same time controlling the (2) ________________ content. Because of its protruding feet the (3) ________________ roller is very effective in compacting plastic soils.

---

(6) (8) (13) (7-28)

FRAME 7-29.

To give the corduroy greater smoothness, the chinks between the logs are filled with brush, rubble, twigs, and so forth. The whole surface of the roadway is then covered with a layer of gravel or dirt. In other words, the roadway must be made as ________________ as possible.

366

(curl) (edges) (7-43)

FRAME 7-44.

Another expedient road surface is the portable timber expedient known as army track, (panel 7-7). This can be used to pass vehicles across sandy terrain. The track consists of 4 x 4 or larger timbers threaded at each end on a ½-inch wire rope and resembles the ties of a railroad track. The timbers must be spaced not greater than the distance which will allow the smallest wheeled vehicle using the road to obtain traction. Army track is a ________________ timber expedient and resembles the ________________ of a railroad track.

---

(1) dust (2) non-jet (7-58)

FRAME 7-59.

Bituminous materials are commonly used as dust palliatives. Chemical agents such as calcium chloride ($CaCl_2$) have also been used with success. However, $CaCl_2$ is generally not used on airfields because of its corrosive effect on aircraft. ________________ materials or ________________ have been successfully used as ________________

367

(1) density (2) moisture (3) sheepsfoot (7-14)

FRAME 7-15.

The task of subbase construction includes the placement and compaction of select material between the subgrade and the base course. The depth of the subbase will depend upon the depth which will affect the structural design or be affected by climatic conditions. The material between the subgrade and base course is called ________________ and its ________________ is determined by the desired bearing capacity or climatic conditions. Sometimes compaction alone will give the subgrade sufficient bearing capacity, and a subbase is not required.

Turn back to bottom of page 7-8.

(smooth) (7-29)

FRAME 7-30.

A more substantial road can be made by placing log stringers (panel 7-3) parallel to the centerline on about 3-foot centers. The corduroy decking then is laid on the stringers and securely pinned to them. The surfaced area is prepared as for the standard corduroy. Therefore the stringer corduroy road is the same as the standard corduroy except that ________________ are used under the decking making it more ________________ than the standard corduroy road.

Turn back to top of page 7-4.

(portable) (ties) (7-44)

FRAME 7-45.

Cable holes are drilled at a 45° angle to the centerline so the cable will bend and prevent individual timbers from moving together. Cables are anchored securely at both ends. The spaces between the timbers are filled in with select material to smooth out the surface. Spaces between timbers in ____________ ____________ shoud be filled to ____________ out the surface.

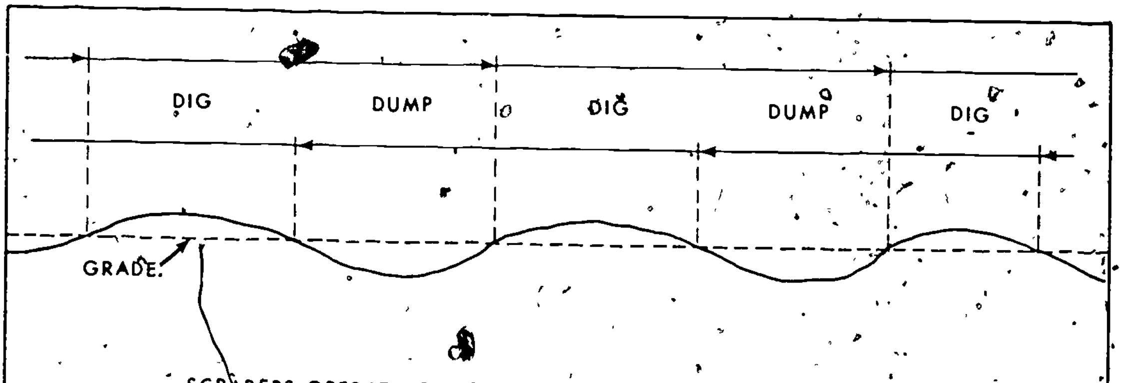
Turn back to bottom of page 7-4.

(bituminous) ($CaCl_2$) (dust) (palliatives) (7-59)

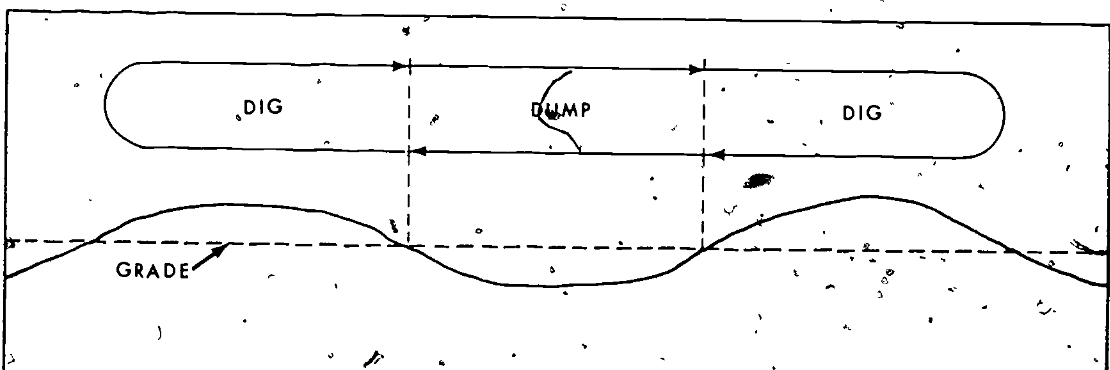
END OF FRAMES

PANELS AND SELF TEST FOLLOW.

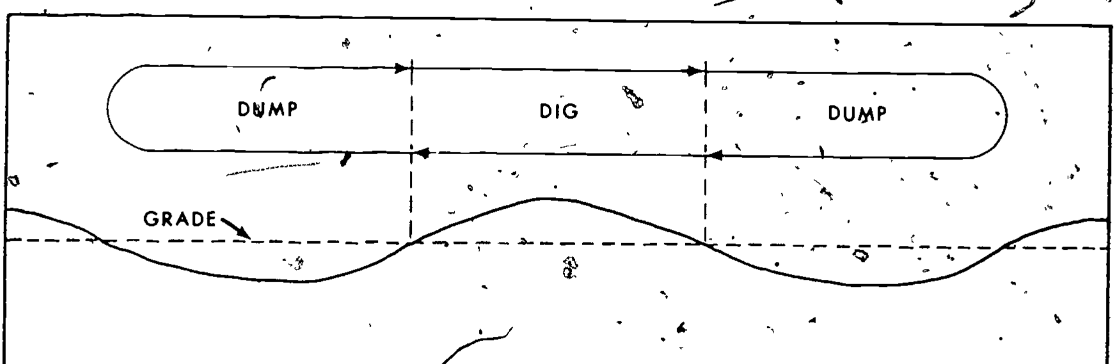
Panel 7-1. Scraper Operations.



SCRAPERS OPERATING A SERIES OF CUTS ALTERNATING WITH FILLS

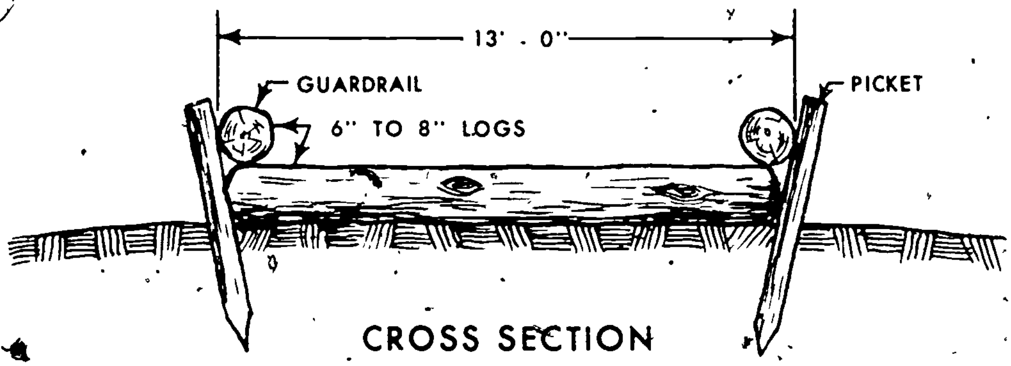


SCRAPERS WORKING TWO CUTS WITH A COMMON FILL



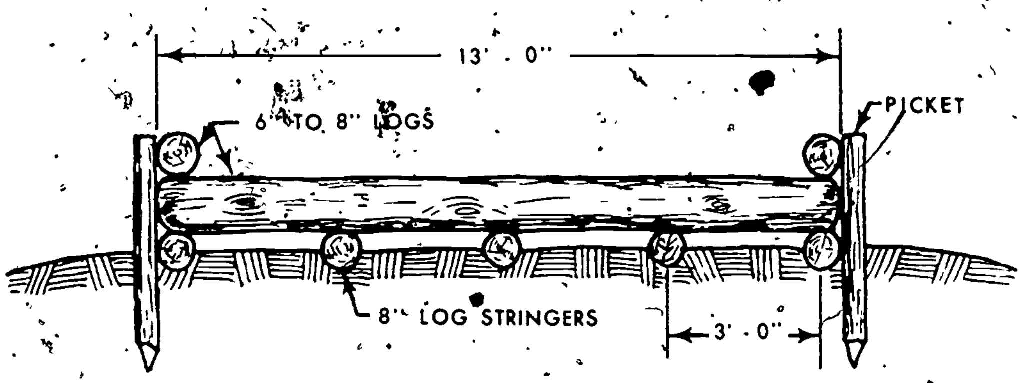
SCRAPERS WORKING FROM SINGLE CUT IN TWO DIRECTIONS

Panel 7-2. Standard Corduroy.



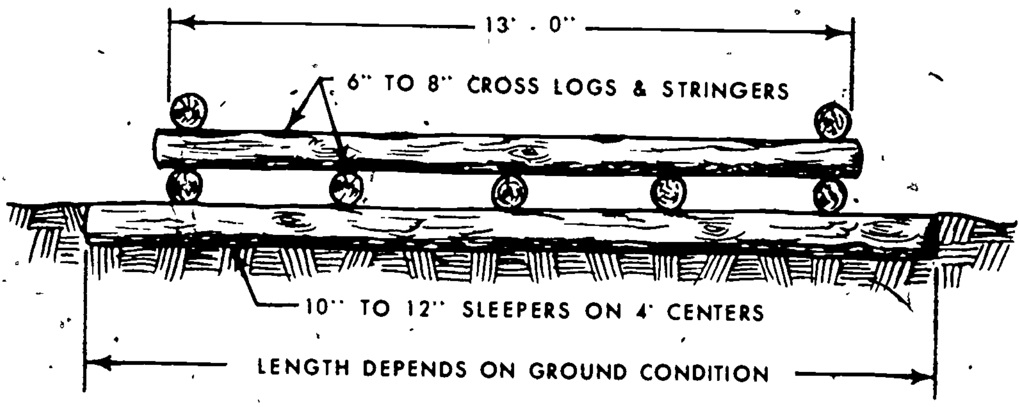
CROSS SECTION

Panel 7-3. Corduroy with Stringers.



CROSS SECTION

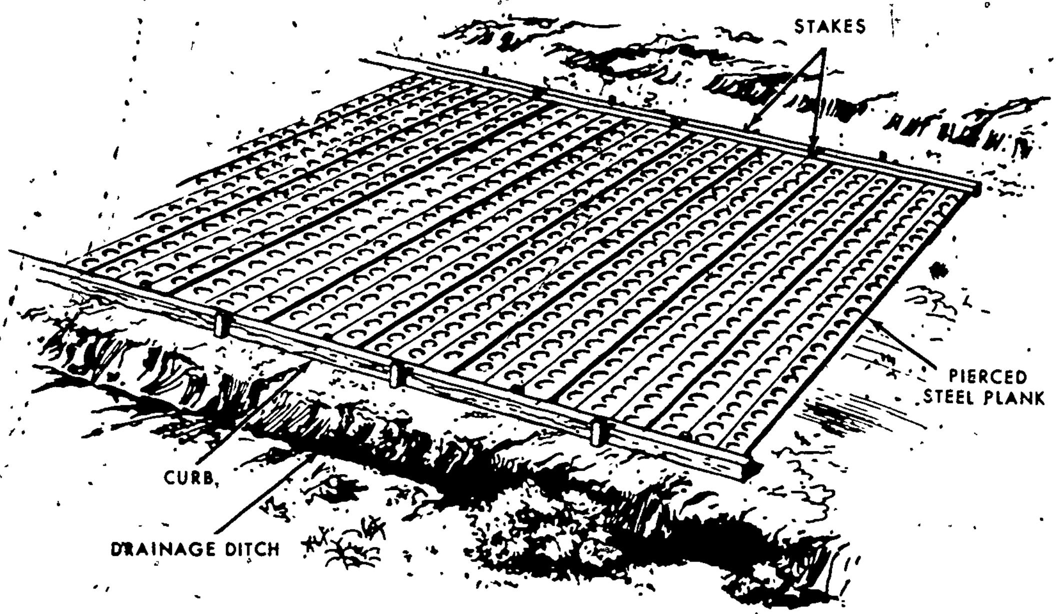
Panel 7-4. Heavy Corduroy.



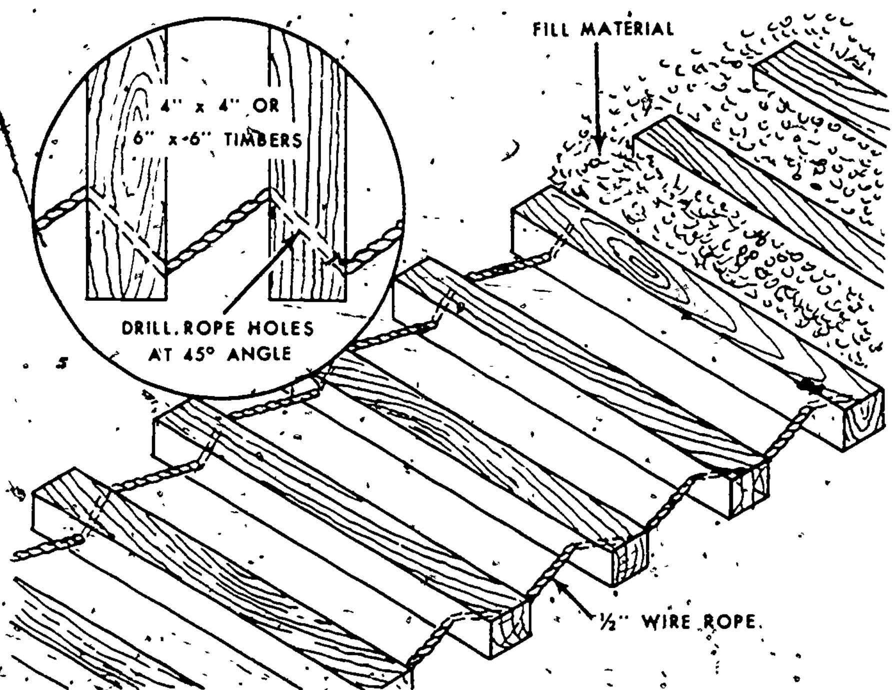
CROSS SECTION

Panel 7-5. Laying a Chespaling Road.

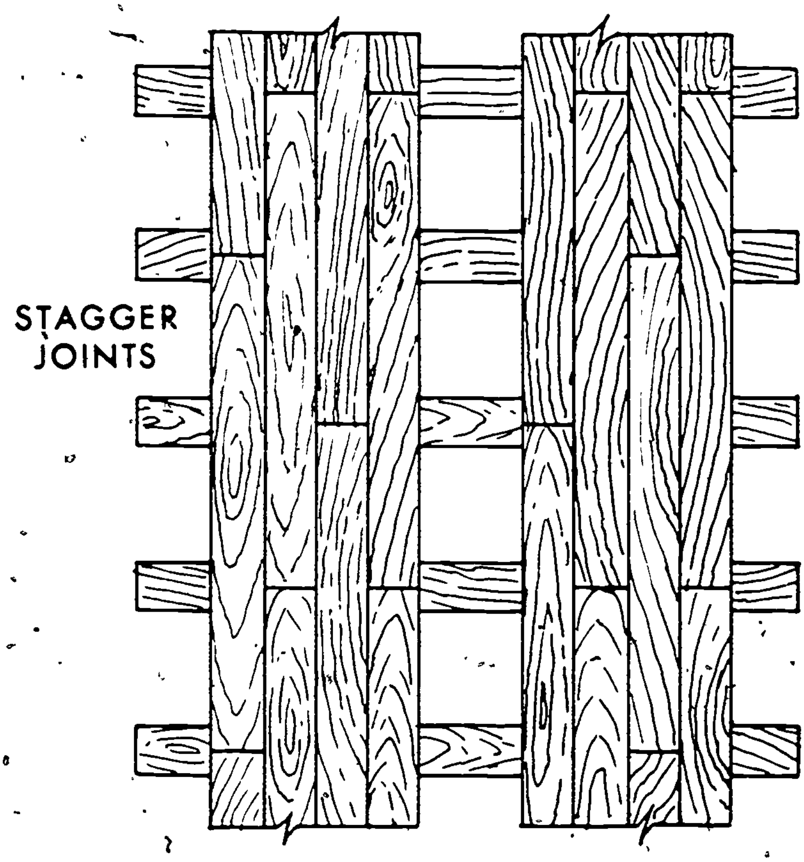
Panel 7-6. Landing Mat Road.



Panel 7-7. Army Track.



Panel 7-8. Plank Tread Road.



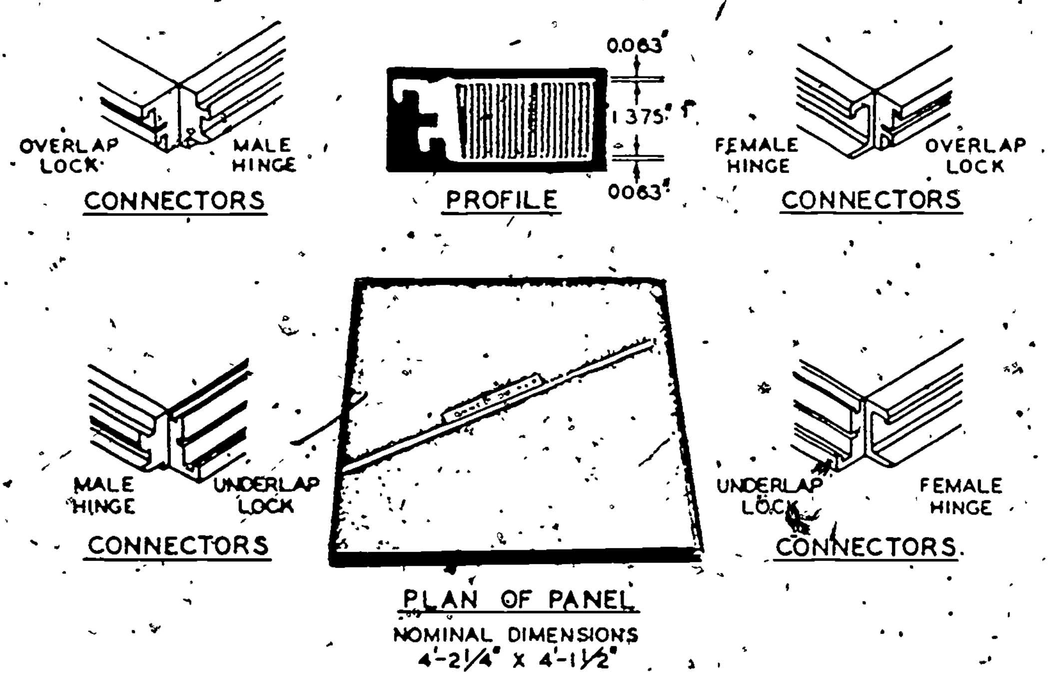
PLAN

CROSS SECTION

Panel 7-9. Load Capacity of Ice.

Thickness of ice in inches	Capacity	Minimum spacing
1½	Individual soldiers	20 paces
2	Individual soldiers	5 paces
4	Single horse or infantry column	65 feet
8	Administrative vehicle artillery up to 2½ tons, or 4-ton vehicles with maximum axle load of 2.7 tons	65 feet
10-13	8-ton (gross) vehicles, including loaded 2½-ton truck	65 feet
12-15	10-ton vehicle (gross)	65 feet
14-18	20-ton vehicle (gross)	65 feet
20-36	40-ton vehicle (gross)	100 feet

Panel 7-10. MX-19 Aluminum Mat.



LESSON 7

SELF TEST

Note: The follwing exercises comprise a self test. The figures following each question refer to a frame or panel containing information related to the question. Write your answer in the space below the question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Do not send in your solutions to these review exercises.

1. In road or airfield construction, the project is broken down into basic construction tasks. What is the key idea causing efficient completion of a construction project? (frame 7-1)

2. Describe the direction of the clearing operation with respect to the disposal area. (frame 7-4)

3. Define grubbing and name the piece of equipment best suited to perform this task. (frame 7-6)

4. A major factor in constructing and maintaining combat-ready roads and airfields is drainage: ditches are essential to good drainage. What equipment is used for digging ditches in hard material? (frame 7-10)

5. In earthwork, all fills should be placed in thin layers and then compacted. What is the purpose of this? (frame 7-14)

6. Base course construction includes the placing and compaction of controlled lifts of blended aggregate. The material for blended aggregate is generally well graded gravel or crushed rock. Discuss the operations which follow and the equipment required once placing of the blended aggregate is complete. (frame 7-18)

7. Support your choice of one of the following factors which must be considered before others when determining the type of expedient to use in the construction of military roads. (frame 7-22)

a. time available
b. desired life of facility
c. terrain features
d. choice of materials

8. Give the characteristics by which road expedients are classified and give the different classifications. (frame 7-23)

9. How is a corduroy road expedient classified? (frame 7-26)

10. Corduroy construction makes an excellent road expedient over muddy terrain. Which of the following types of corduroy construction is used most frequently? (frame 7-27 and panel 7-2)

a. stringer c. standard

b. heavy d. sleeper

11. Diagonal corduroy is preferred for heavy traffic. What is the purpose of diagonal construction? (frame 7-33)

12. Chespaling is especially useful as a hasty expedient for traversing muddy or sandy terrain. What must be done to chespaling in the way of maintenance? (frame 7-36 and panel 7-5)

13. What should be used with metal landing mats to make them remain stable during periods of heavy rainfall? (frame 7-40)

14. Over what type terrain is army track most effective? (frame 7-14)

15. Which type of tread road is the most important? (frame 7-48 and panel 7-8)

16. In actic regions, excellent roads can be made of snow. Besides the compaction of the snow, what other step is most essential? (frame 7-49)

17. How many paces apart should individual soldiers be spaced when crossing ice 1½ inches thick? (frame 7-50 and panel 7-9)

18. Landing mats used as portable surfaces for airfield runways should provide a structural load distributing medium and wearing surface. What category of landing mats should be used when the subgrade CBR is 7? (frame 7-53 and panel 7-10)

19. What is the purpose of impermeable membranes when used as a surface for airfields? (frame 7-52 and panel 7-55)

20. What dust palliative is not normally used at airfields because of its corrosive effect on aircraft? (frame 7-59)

ANSWERS TO SELF TEST

LESSON 1 ------------------Construction Requirements and Design Criteria.

All references are to lesson frames and to panels.

1. Although engineer units are responsible for maintaining military roads, they provide only major maintenance of Army airfields; that is, work beyond the capability of the using unit. Minor maintenance of Army airfields, therefore, must be done by units using the installation. (frame 1-6)

2. There are six principal tasks in road and airfield construction: clearing, grubbing, stripping, earthwork, drainage, and surfacing. Clearing is the removal of timber and surface boulders; stripping is the removal of objectionable top soil. Removal of stumps and roots is grubbing; earthwork is referred to as grading and essentially means cutting off high spots and filling in low places to get a grade level enough. It is the most important construction task because the most time and effort are normally required. Drainage is the removal of undesired volumes of water and surfacing is the final placement of whatever wearing surface will be used. (frames 1-7, 1-8)

3. Any sketch which is similar to panel 1-1 showing the wearing surface on top, the base in between and the subgrade on the bottom (panel 1-1).

4. Superelevation refers to the slope of a road around a curve; that is, difference in elevation between "outside" and "inside" edges of the traveled way. (frame 1-17)

5. Traveled way (single lane) . . Minimum — 11½ feet.
Traveled way (two lanes) . . Minimum — 23 feet.
Shoulders (each side) . . . . . Minimum — 4 feet.
Clearing . . . . Minimum — 6 feet on each side of roadway. (panel 1-2)

6. Normal maximum . . . . . . 10 percent
Desirable maximum . . . . tangents and gentle curves, less than 6 percent; sharp curves, less than 4 percent. (panel 1-2)

7. Vertical curve lengths are determined by the following specifications:

Invert curves . . . . 100 feet minimum for each 4 percent algebraic difference in grades.

Overt curves . . . . 125 feet minimum for each 4 percent algebraic difference in grades. (panel 1-2)

8. The slope of a road with a paved crown is set at ¼ to ½ inch per foot to the centerline. (panel 1-2)

9. The overrun is located between the runway and the approach zone. (panel 1-3)

10. The location of roads and airfields depends on the military necessity. However, dense forest and rough terrain require extensive clearing and earthmoving, while use of existing facilities usually saves time. If the military situation permits, good planning generally means maximum use of existing facilities. (frame 1-3)

11. Item 5, panel 1-2, requires a minimum of one turnout every 1/4 mile for single lane roads. Thus, $(2 \div 1/4) - 1 = 7$ turnouts are required for a 2 mile stretch of single-lane road. (frame 1-10 and panel 1-2)

12. Adding to the length of the runway (3000) the two lengths for the overruns (300 + 300) gives a total length of 3600 feet. (panels 1-3, 1-4)

13. The increase in altitude in this case is 2000 feet above the altitude of 1000 feet, so the TGR is increased by 20%. (item 2, panel 1-5). Thus:

$2000 \times 1.20 = 2400$ ft

The increase in temperature is 10 degrees and the TGR is less than 5000 feet, so the runway length must be increased by an additional 4%. (item 3, panel 1-5).

$2400 \times 1.04 = \mathbf{2496}$ ft.

(frames 1-30, 1-31 and panel 1-5)

14. Since this runway is in a rear area, the safety factor is 1.5. (item 4, panel 1-5). Therefore:

$2496 \times 1.5 = 3744$ ft.

The effective gradient is 1% over 2%, so the runway length must be further corrected by adding another 8%. (item 5, panel 1-5).

$3744 \times 1.08 = 4043.5$. Rounding this figure up to the next even hundred, (item 6, panel 1-5), the final runway length becomes **4100** feet. (frames 1-32, 1-3, and panel 1-5)

15. The length of runway found in panel 1-9 is 450 feet and adding the two overrun lengths of 100 feet each gives a total length of 650 feet. (panels 1-7, 1-8, 1-9)

16. Panel 1-9 shows minimum width for a service road of a heliport in a forward area as being 11.5 feet. (panel 1-9)

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All references are to lesson frames and lesson panels.

1. The first purpose of reconnaissance is to find a solution to the tactical need. The most important factor to consider is the tactical need. (frames 2-1 and 2-3)

2. A **road** reconnaissance is made to obtain information about existing roads, primarily for immediate use and establishment of a route. It may include estimates of the practicability of improvement, and the engineer work in conditioning a road to accommodate specified traffic and loads. (frame 2-4)

3. Section II of DA Form 1248 provides for detailed information on alinement, drainage, foundation and road surface. (frame 2-6 and panel 2-1)

4. Reportable items of section III of DA Form 1248 are:

(a) Overhead obstructions, less than 14 feet or 4.25 meters, such as tunnels, bridges, overhead wires and overhanging buildings.

(b) Reductions in road widths which limit the traffic capacity, such as craters, narrow bridges, archways and buildings.

(c) Excessive gradients (above 7 in 100)

(d) Curves less than 100 feet (30 meters) in radius.

(e) Fords. (panel 2-1)

5. The purpose of **periodic** road reconnaissance is to maintain complete data on the condition of roads currently in use. The information obtained is normally posted on a situation map. To insure that roads are **NOT** maintained longer than needed, maintenance requirements based on periodic road reconnaissance are coordinated with the principal users. (frame 2-7)

6. When a new road is determined to be necessary, the first step is called location reconnaissance. (frame 2-8)

7. Locating portions of the new road along and over existing roads, railroads, or trails is always a primary goal. The use of existing facilities shortens construction time and, in many cases, provides better roads than can be built from the ground up on the limited time available during combat operation. (frame 2-10)

8. The organic soils of a swampy area are the most difficult to drain and have the poorest bearing capacity. Excessive engineer effort and possible road failure can normally be avoided when the types of soils are accurately identified during a location reconnaissance. (frame 2-13)

9. Natural drainage is usually good drainage. Locating a road to take advantage of natural drainage also reduces the construction effort required. Long stretches of flat ground often drain poorly. Locating a road along ridges and stream lines usually takes best advantage of natural drainage. (frame 2-14)

10. A geologist's advice on ground-water tables is especially useful in location reconnaissance. It is also needed in determining effects of any rock formations,

essentially to avoid extensive blasting work on cut and fill operations and the danger of landslides and rock falls, particularly where clay or shale layers are present. (frame 2-15)

11. Rock formations are also important considerations in location reconnaissance in regard to possible quarry sites for construction materials (fill, base course and surface course), ground-water tables and excessive blasting work. (frame 2-16)

12. Ease of future maintenance is a factor. In areas of rain or snow, locating the road on the sunny side of slopes and canyons minimizes the possibility of the road's becoming impassible for long periods and eases maintenance work. (frame 2-19)

13. At times, tactical and engineering considerations are in conflict with the best location based on the preceding criteria. In these cases, the location criteria must be subordinated. An overriding tactical consideration, for example is that the road must be ready for use when the situation requires it. Improvements may be effected at a later date. (frame 2-20)

14. Convenient sites for development as bivouac areas and supply points may be important tactical requirements, as well as provision for artillery and armor units to leave the road to fire emergency missions. The latter would also enable traffic using the road to take cover in the event of an air attack. (frame 2-21)

15. Map reconnaissance and ground reconnaissance are two methods used for determining road location. Study of maps and aerial photographs can readily eliminate obviously undesirable routes and indicate one or more possible routes where ground reconnaissance might be made, minimizing wasted effort. In the final analysis, map reconnaissance supplements ground reconnaissance, and one or both are employed with location reconnaissance. (frame 2-23)

16. A ground reconnaissance can supplement the hasty location of a route. (frame 2-25)

17. The engineer study in a deliberate location should contain evaluations of several possible routes in terms of design standards and location criteria. (frame 2-29)

18. Other primary control points include terminal points and the intermediate points through which the road must pass. (frame 2-30)

19. An example of third order control features is where a road can follow general contour directions. (frame 2-32)

20. Tertiary control features are discarded before secondary and secondary features yield to primary. (frame 2-33)

21. Sampling 10 percent of the area and applying the result to the entire area is usually sufficient coverage. In small areas a higher percent cruise maybe made. (frame 2-35)

22. A map plotting all pertinent data is drawn. Soil classification data at typical locations are included on the map. (frame 2-39 and panel 2-3)

23. The elements which must be evaluated to base final location on are alinement, grade, and earthwork. (frame 2-42)

24. The time spent in the preparation of a paper location is repaid in better alinement and is directly reflected in both the decreased engineer effort needed for construction and the increased traffic capacity of the finished road. (frame 2-47)

25. Road A although the most direct, would not be practical primarily because it crosses the swamp. It also crosses steep grades and requires considerable clearing. The road also does not pass near the quarry — a source of construction material.

Road B also crosses steep grades and in addition a portion of the lake must be crossed. The lake also has steep banks at the crossing sites. Some clearing is also required. The road does not pass near the quarry.

Road D avoids the swamp and the lake and steep grades but requires extensive clearing. It is also the longest route. It passes nearest to the quarry but this is outweighed by the amount of clearing necessary.

Road C is the best route. It follows contour direction, avoids the swamp and lake, passes within hauling distance of the quarry, and requires little clearing. The least construction effort would be required for Road C. (frame 2-34 and panel 2-4)

All references are to lesson frames and lesson panels.

1. Airfield reconnaissance differs from road location reconnaissance in two major considerations. First — an airfield project involves more manhours, more equipment hours, and more material than a road project. Secondly — air traffic, by its very nature, imposes more severe design criteria (see panel 1-4, lesson 1) than does vehicular traffic. (frames 3-1 and 3-2)

2. Reconnaissance missions must be based primarily on user requirements, which, in turn, are often governed by the tactical air support requirements of ground forces. The various headquarters must maintain close liaison with the Air Force and with each other. Each must know what reconnaissance the other is doing or has a need for. (frame 3-6)

3. There are six steps in airfield reconnaissance: planning, briefing, preliminary study, air reconnaissance, ground reconnaissance, and reporting. (frame 3-10)

4. The preliminary study, represents the initial work. The party studies the information obtained during the briefing, conducts a map reconnaissance of the area, studies air photos, delineates soil boundaries, assembles other preliminary information, and the actual record is planned. (frame 3-12)

5. The purpose of the ground reconnaissance is to answer most questions or to verify questions formed from the air. (frame 3-15)

6. The prompt submission of reconnaissance reports is controlled by time-of-report schedules. (frames 3-9 and 3-17)

7. Existing airfields are marked with a five mile circle. (frame 3-20 and panel 3-1)

9. A ratio of 50:1 should be used for determining the diameters of circles marking obstructions such as radio towers. (frame 3-21 and panel 3-1)

9. Referring to panel 3-2, reading along the funnel with the 40:1 glide angle until the horizontal ground distance is 6,000 feet, yields a permissible height of 150 feet. (frame 3-25 and panel 3-2)

10. The pilot considers such flying problems as approaches, mental hazards, and physical obstructions, as related to combat type planes which may use the proposed airfield.

The engineer observer is not as familiar with flight requirements and characteristics of aircraft. He is familiar with the construction problems which may be encountered, and assesses the potential site in terms of construction effort. (frames 3-27 and 3-28)

11. In reconnoitering a tentatively selected site, at least three passes are made at 300 feet and the final circuit is flown at 200 feet. (frame 3-31 and panel 3-3)

12. L = air speed (ft/sec) x average flight time (sec) Since the flight time is in seconds, count air speed to ft/sec,

$$\frac{100 \text{ mph} \times 5{,}280 \text{ ft/ mi}}{3600 \text{ sec/hr}} = 146.666 \text{ ft/ sec}$$

The estimated runway length is then,

$$146.666 \times 55 = 8{,}066.83 \text{ ft, say } 8{,}000 \text{ ft}$$

13. En route to the site or a general area, the engineer observer would note borrow pits, quarry sites, and rail or road access routes. He would also note any obvious errors on maps that had been studied.

As in air reconnaissance, enroute to the site to be investigated, the reconnaissance party should note and properly record access routes, location of construction materials, and the positions of potential water points. (frames 3-29 and 3-34)

14. The clearing and grubbing effort is estimated by timber cruising, the same as for roads, (frame 3-39)

15. Normally, elevations are taken at each 500-foot interval and at any breaks or slope changes. This interval however may be increased to 1000 feet in flat country. (frame 3-40)

16. The statement "glide angle is excellent" is transmitted as "GOLF UNQUESTIONABLE." (frame 3-42 and panel 3-4)

17. As in road location, the selection of airfield sites is usually a compromise between engineering, operational, and tactical requirements. (frame 3-46)

18. From panel 1-4 (Lesson #1), read under "rear" and across from "maximum grade change per 100 ft" the value of 1.5%. (frame 3-49 and panel 1-4)

19. The use of the long straight stretches of the existing road as a "center core" for the airstrip should be considered. (frame 3-51)

20. Minimum criterion pertaining to interfering obstructions would require the approach zone be free of obstructions at each end of the flightstrip. (frame 3-53)

21. Besides manmade and natural obstructions, there may be situations and layouts which might present a **mental** hazard to the pilot. An airfield on a plateau with steep - sides falling away immediately beyond the overruns may have perfect approaches, for example, but pilots will always land well down the runways. A canal, ditch, or pole line at the end of a runway has the same effect. (frame 3-54)

22. The Air Force All Weather Service (AWS) maintains meteorological information for all populated areas of the world. (frame 3-55)

23. Topography will determine the extent of drainage and earthwork required. (frame 3-58)

24. It is most important to examine hydrological conditions and soil characteristics because drastic changes may take place between wet and dry seasons. This

makes any evaluations of hydrological conditions made during the dry season misleading. (frame 3-57)

25. Whether a base course is needed and the thickness of the base course are dependent on the characteristics of the soil. (frame 3-59)

LESSON 4 — Layout Procedures, Construction Staking, and Alinement.

All references are to lesson frames and lesson panels.

1. Control consists of vertical control points (or bench marks) for the vertical component and horizontal control points for the horizontal component. The control points are frequently called hubs and are short square wooden stakes (2" x 2") driven flush with the ground. Vertical control is generally established by selecting a convenient bench mark as a datum and referencing all other elevations to it. Horizontal control points may be tied into a local grid system. (frames 4-1 to 4-8)

2. The primary function of construction stakes is to indicate the alinement of a construction facility, to aid equipment operators, to control specifications and prevent excessive work. (frame 4-11)

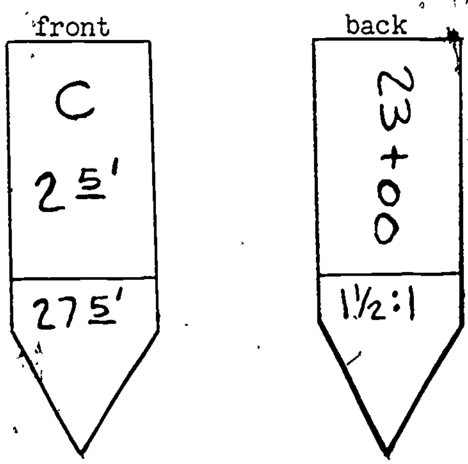
3. Centerline or alinement stakes are placed on the centerline of a road or airfield to indicate it's location, alignment, and direction. (frame 4-16)

4. The side of the centerline stake which faces the starting point is designated as the front of the stake and is marked with the centerline symbol ℄ and applicable PC for point of curvature or PT for point of tangency. Also marked on the front of the stake is the distance from the origin and the fractional part of the station. On the back of the centerline stake, the information on cut (C) or fill (F) required at each station is written. (frame 4-20 to 4-22)

5. The stake is 200 feet from the origin and a 1-foot fill is necessary at this location. (frame 4-25)

6. Slope stakes are used to define the limits of grading. (frame 4-26)

7.



(frame 4-36)

8. Offset stakes are used to eliminate resurveying portions of a road or an airfield and accomplish their task as reference points by being placed beyond construction limits. (frame 4-38, 4-39, 4-41, 4-42)

9. Horizontal alinement consists of a series of straight lines called tangents connected by horizontal curves. In preparing horizontal alinement, intersecting tangents are laid out first and are later connected by curves. (frame 4-47)

10. 1. Keep number of tangents to a minimum.

2. The connecting tangents of new roads should approach at right angles to existing roads.

3. Tangents should be selected so as to avoid excessive grades.

11. PI is defined as the point where two tangents intersect (Point of Intersection). Angle of intersection (I) is the exterior angle formed at the PI and also the angle subtended between the intersection of the radius points at 0 (panel 4-5).

The point where the curve begins or leaves the tangent is called the point of curvature (PC) and the point where the curve joins the tangent or where the curve ends is called the point of tangency (PT) (panel 4-5).

12. When hasty type roads and airfields are built in forward areas, high precision is not essential; a fairly good curve can be staked in by the eye and then adjusted as construction proceeds. Another simple way of staking out a curve in a forward area would be to have the driver or a truck make a gradual turn and use the wheel tracks to stake out the curve. (frames 4-68 and 4-69)

13. A compound curve is known as a reverse curve when the two curves go in opposite directions. (frame 4-71)

14. Vertical alinement of roads and airfields is that portion of the design process that is concerned with the establishment of grades and the determination of the vertical connecting curves between these grades. (frame 4-73)

15. The parabolic curve is usually used for vertical curves because it provides smooth transition and the essential dimensions can be easily calculated by the surveying crew in the field. (frames 4-83 and 4-84)

16. Two types of parabolic curves are used. The overt (convex) curve is used to curve over a hill. The invert (concave) curve is used to provide transition from a down grade to an upgrade or to a level alinement (tangent). (frames 4-85 and 4-87)

17. PVI — The point where two tangent grade lines intersect is called the point of vertical intersection.

PVC — The point where the curve leaves the gradeline is called the point of vertical curvature.

PVT — The point where the curve joins the grade line is known as the point of vertical tangency.

1. Entering the table at 4 feet in column 1 and continuing horizontally to column 6, the value for a 24-foot cut with 1 to 1 side slopes is 415 cu yd. Continuing horizontally column 10 indicates that 30 cu yd must be added for the 2 additional feet (24 + 2 = 26 ft), and column 11 indicates that 30 more cu yd must be added for 1½ to 1 slopes. Thus:

415 + 30 + 30 = 475 cu yd

Then: $\frac{100}{100}$ x 475 = 1,425 cu yd (frame 5-7 and panel 5-1)

2. Triangles 7 and 8 = 3.4 x (5 + 15) = 3.4 x 20 = 68
9 and 10 = 3.4 x (30 - 0) = 3.4 x 30 = 102
170

Then: $\frac{170}{2}$ = 85 sq ft (frame 5-24 and panel 5-2)

3. From panel 5-6:

End area of cut at station 33 + 00 = 1,156
End area of cut at station 33 + 90 = 1,345
Sum of end areas = 2,501 sq ft

Since the sum of the end areas is greater than 1,673.9 sq ft break the sum 2501 into two portions — 1,200 and 1,301.

Then, from panel 5-3:

For the figure 1,200 the volume is,

2,200 (column heading) + 22.22 (column 0.0) = 2,222.22

For the figure 1,301 the volume is,

2,400 (column heading) + 9.26 (column 0.0) = 2,409.26
Total volume = 4,631.48 cu yd

Since L = 3,390 - 3,300 = 90 ft, the total volume between stations 33 + 00 and 33 + 90 is,

$\frac{4{,}631.48 \times 90}{100}$ = 4,168.71 say **4,170** cu yd (frames 5-30, 5-32, panels 5-3, 5-6)

4. Panel 5-4 shows the factor of cut to fill is based on 125 cubic yards of excavation required to make 100 cubic yards of fill, for fills 2 feet high and under (100/125 = 0.8). For fills over 2 feet high, the factor is 0.85. (frames 5-40 and 5-41)

5. The mass diagram is a graph on which the algebraic sum of the embankment and corrected elevation is plotted against linear distance. The linear distance is always plotted as the abscissa and the algebraic sum of the embankment and excavation is plotted as the ordinate. (frame 5-59)

6. From panel 5-7, the conversion factor for in place sand to compacted sand is 0.95. Therefore the shrinkage is 1.00 - 0.95 = .05 or 5%. Thus: 1200 x 1.05 = **1260** cu yds to be excavated. (frame 5-76 and panel 5-7)

7. The balance line is a horizontal line between any two points on the mass line where excavation equals embankment. The maximum length of the balance line is predetermined on the basis of an efficient haul. (frame 5-94)

8. A balance line above or below any other balance line represents the total net yardage that is to be moved from cut to fill, disregarding the yardage which is balanced within any 100 foot distance that has both cut and fill. (frame 5-103)

9. The direction of haul will be from right to left. This is because this is a sag hump. (frame 5-115)

10. The second method entails scaling off the volume from ordinates of the mass diagram. This method is not as accurate but is of sufficient accuracy for most situations. (frame 5-117)

11. Materials to be imported and mixed with subgrade soils for subgrade stabilization are included in earthwork computations, but base course or paving materials to be placed above the subgrade are not included. (frame 5-2)

12. Cross sections are plotted for each 100-foot station on the adopted centerline for runways and road tangents. They are also plotted at any intermediate place where there is a distinct change along the centerline, and where the natural profile and the gradeline correspond (from cut to fill).

Also, a cross section would be plotted at intermediate places between stations when the surface on either side of the centerline is uneven enough to require plotting in order to represent properly the volumes indicated between the station cross sections. (frames 5-12 to 5-14)

13. The area described contains triangles 6, 7, 8, 9, 10 and 11. They can be paired as follows:

Triangles	6	= 3 x (5)	= 15
	7 & 8	= 3.4 x (5 + 15)	= 68
	9 & 10	= 3.4 x (30 - 0)	= 102
	11	= 2.1 x (15)	= 31.5
		Total	216.5

dividing by 2 equals 108.25 say 108 ft^2

(frame 5-23)

14. "Counting the squares" consists of counting the enclosed squares and multiplying the result by the area in square feet of one square. This gives the area of the cross section in square feet. The area in square feet of one square is determined by the horizontal and vertical scales used in plotting the cross section. (frame 5-18)

15. Reading in table from panel 5-4, across the line marked cut-2 is the value 1,100. This is the volume of fill that can be made from a cut per 100 feet of length.

Multiplying:

(1,100) x (3.5) = 3850 C.Y. (panel 5-4 and frame 5-41)

16. A tentative runway gradeline is set as a guide in properly assigning equipment prior to detailed computation of earthwork quantities. Establishment of a tentative grade enables work to proceed before detailed computation of earthwork quantities are made. (frame 5-42 to 5-44)

17. One method of establishing the tentative grade line is to plot the centerline profile and the profiles of the shoulder edges. The tentative subgrade grade line is then plotted on the profile bearing in mind minimum earthwork and efficient haul limits.

The grade line corrected for transverse slope is then plotted on the corresponding runway and shoulder edges. The areas between the grade line and the profile are then obtained. Because cuts should roughly balance fills, the sum of the areas above the grade line is balanced against the sum of the areas below the grade line. The tentative grade line is shifted until the areas obtained are roughly in balance. (frames 5-45 to 5-49)

18. The last step common to both methods of computing borrow pit volumes is to determine cross sectional areas and then determine the volume. (frames 5-50 and 5-52)

19. Referring to panel 5-6, reading down column (3) excavation and across from station 41 + 00 gives a value of 196 cubic yards. (frame 5-67 and panel 5-6)

20. The two formulas needed are:

(1) excavation - strip volume = net excavation

(2) embankment + strip volume = net embankment

first net excavation:

```
  2169
 - 214
  1955 cubic yards
```

next net embankment:

```
  1365
 + 214
  1579 cubic yards
```

(frames 5-71, 5-72 and panel 5-6)

21. Column 6 deals with the product of the net excavation and the proper shrinkage or swell factor. In terms of columns, column 5 is multiplied by 0.9. (frame 5-74 and panel 5-6)

22. Positive values are excavation quantities; negative values are embankment quantities. (frame 5-60)

23. An ascending mass line in the diagram indicates an excess of excavation, and a descending mass line an excess of fill along the portion of the area for which the mass diagram is drawn. (frame 5-92)

24. When the mass line forms summit humps, the haul will be from the lower to the higher station numbers, when the mass line forms sag humps, the haul will be from the higher to the lower station numbers. (frame 5-93)

25. Generally, the average length of haul is approximately equal to the length of a horizontal line drawn midway between the peak of the mass line and the balance line. (frame 5-113)

All references are to lesson frames and lesson panels.

1. In the construction sequence, drainage is listed immediately after the clearing and grubbing phase.

Drainage construction must precede earthwork for two reasons. First, most culverts must be installed in order to allow earthwork operations to progress without interruption; second, fills and cuts must be protected from the effects of rain and overland flow during all phases of construction. (frame 6-4)

2. Standing water on road, runway, and parking area surfaces not only decreases operating efficiency but will eventually saturate the subgrade, causing failure. Sheet flow (moving water) that is too deep or moving too fast will erode the surface over which it moves. Surfaces are built with gentle slopes designed to remove standing water and control sheet flow with minimum damage to surfaces and subgrades.

A minimum slope of 0.5% is necessary to make ditches self-cleaning; the maximum desirable slope is set at about 4%. When the slope becomes greater than the desired maximum, the ditch must be lined with riprap, sodded, or paved. (frames 6-8, 6-16)

3. For normal road construction requirements the deep V ditch is most suitable; where extra capacity is needed or where the soil erodes easily the trapezoidal ditch is best; the shallow V ditch is built near airfield runways. (frame 6-14)

4. On sidehill cuts and steep grades, checkdams are placed in side ditches to reduce the rate-of-flow (slow the water) and prevent erosion.

Side slopes of the ditch immediately above and below checkdams (panel 6-4) require protection from erosion and scouring. To accomplish this, a weir notch big enough to discharge the anticipated runoff is cut in the middle of the checkdam to prevent backed-up water from cutting at the edges of the checkdam. An apron, extending from the downstream face of the checkdam, is needed to prevent scouring. (frames 6-17, 6-18)

5. Formula for spacing of checkdams:

$$S = \frac{100\ H}{A - B}$$

minimum value of H is 1 foot

minimum value of B is 2 percent

A is given as 7 percent

$$S = \frac{(100) \times (1)}{7 - 2} = \frac{100}{5} = 20 \text{ feet}$$

(frame 6-19 and panels 6-4, 6-5)

6. Formula for number of checkdams is

$$N = \frac{\text{length of ditch}}{\text{spacing}}$$

the spacing is calculated as

$$S = \frac{100\ H}{A - B} = \frac{(100) \times (2)}{4 - 2} = 100 \text{ feet}$$

the number can now be calculated:

$$N = \frac{600}{100} = 6 \text{ checkdams}$$

(frame 6-21 and panel 6-6)

7. Whenever natural drainage channels cannot be diverted economically from roads, taxiways, and occassionally runways, facilities must be provided to permit cross-drainage to flow under them. Culverts are used for this purpose. They provide cross-drainage at low points in a fill, provide ditch relief, and continue side ditches at intersections. (frame 6-24)

8. Most pipes used for culvert construction are made of either reinforced concrete, cast iron, or corrugated galvanized metal. Pre-formed corrugated metal pipe (CMP) is the easiest to place.

The other choices are too time consuming to compete with CMP. (frame 6-25)

9. Although the resulting structures are not as strong as CMP or box culverts, expedient drainage structures can be built using steel (oil, gasoline, or asphalt) drums. (frame 6-30)

10. The placement of culverts in meandering channels should be made after proper realinement of the stream is made (when needed). Some construction such as building dams and digging new channels for shifting the stream to proper alinement may be required. (frame 6-34)

11. On an 8 percent grade, ditch relief culverts should be placed 300 feet apart. (frame 6-35)

12. $A = \frac{W_1 + W_2}{2} \times H + 100\%$

$$A = \frac{8 + 6}{2} \times 6 + 100\% = 84 \text{ sq ft}$$

(frame 6-42 and panel 6-12)

13. Using Talbots nomograph, the value of 24 inches is read as the diameter of round pipe. (frame 6-44 and panel 6-14)

14. From panel 6-15, a 48 in. pipe = 12.57 sq ft

Then: $\frac{25}{12.57} = 1.98$

Use 2 pipe of 48 in. diameter (frame 6-46 and panel 6-15).

15. $D_{max} = 2/3\ F$

$D_{max} = 2/3\ (7.8 \times 12) = 60.4$

Use 60 in. diameter pipe (from panel 6-15) (frame 6-51 and panel 6-18)

16. From panel 6-19, under the "120,000 lb plane" heading and across from the 16 gage pipe, the cover requirement is read as 4.0 feet. (frame 6-53 and panel 6-19)

17. ½D or $\frac{36}{2}$ = 18 inches

18. The object of subsurface drainage is to lower the water table by tapping the ground water and carrying it off in a pipe or ditch. (frame 6-60)

19. In road or airfield construction the water table should be a minimum of 5 feet below the facility. (frame 6-61)

20. Deep open ditches are not usually constructed in long stretches but are more commonly employed in short stretches at critical points. However, in many cases, such ditches are a traffic hazard and they are also subject to erosion. (frame 6-67)

21. A tile drain is the same as the French drain except that the trench may be filled with gravel in lieu of crushed stone and a pipe is placed near the bottom (panel 6-21). The pipe is usually 6 inches in diameter although 8- and 10-inches pipes are also used. (frame 6-72)

All references are to lesson frames and lesson panels.

1. A road or airfield construction project is broken down into basic construction **tasks** which are performed in logical **phases** sequence. After one task of the project, such as the clearing of trees and brush, has been completed on a certain area, the second construction task of stripping the area is begun. At the same time, the first task of clearing would be started in another area. Thus, time and effort can be saved by performing several types of construction tasks simultaneously. (frame 7-1)

2. Clearing should start at the point of disposal and fan outward so that trees and brush can be pushed over a cleared area. If logs are cut from felled trees, this should be done in the disposal area to avoid interference with the clearing operation. (frame 7-4)

3. Grubbing is the removal and disposal of stumps and embedded boulders left in the area after clearing. Crawler dozers are very efficient for removing stumps up to 30 inches in diameter. (frame 7-6)

4. For trenches, the ditching machine is normally used. For harder materials, the back hoe should be used. For cutting and shaping open ditches, the grader and dozer are employed. (frame 7-10)

5. The reason for placing the fill in thin layers and then compacting is to insure uniform density throughout the mass while at the same time controlling the moisture content. (frame 7-14)

6. Once the materials are blended (if needed), compaction is obtained from pneumatic-tired rollers with final rolling made by three-wheel rollers. As with subgrades, high spots are removed and final shaping is done with the grader. (frame 7-18)

7. The choice of the material used is important in securing best and quickest results. With a choice of materials, the principal factors which will determine the **type** of expedient used will be the time available for construction, desired life of the road, and the type of terrain the road must traverse. (frame 7-22).

8. In practice, the life of a facility will depend greatly on the time used to build it. Expedient roads can be classified as "hasty" expedients when they are to be built quickly, and last only a short time, and as "heavy" expedients when they require more time to build and last longer when built. (frame 7-23)

9. A corduroy road can be classified both as a heavy and terrain expedient. (frame 7-26)

10. The most frequent type of corduroy construction is the standard type. (frame 7-27)

11. Putting the decking at an angle decreases the impact load, since each log supports only one wheel at a time and there is longitudinal as well as lateral weight distribution. (frame 7-33)

12. Chespaling must be kept wet to prevent the saplings from becoming brittle and breaking. (frame 7-36 and panel 7-5)

13. Metal landing mats can also be used on mud, but they are not satisfactory on mud when used alone. Mud pumps through the joints and the mat sinks until it becomes ineffective. Experiments have proven that with the use of membrane to prevent the pumping of the mud, a fairly effective expedient can be constructed. (frame 7-40)

14. The army track is excellent in sandy terrain. The track consists of 4 x 4 or larger timbers threaded at each end on a ½-inch wire rope and resembles the ties of a railroad track. The timbers must be spaced not greater than the distance which will allow the smallest wheeled vehicle using the road to obtain traction. (frame 7-44)

15. The most important single type of tread road is the plank tread road (panel 7-8). Sleepers 12 to 16 feet long are first laid perpendicular to the centerline, on 3-to-4-foot centers depending on the loads to be carried and subgrade conditions. Then place 4 x 10-inch planks parallel to the traffic to form 2 treads, about 36 inches apart. (frame 7-48 and panel 7-8)

16. Emphasis should be placed on making grades and curves as gentle as possible. (frame 7-49)

17. From panel 7-9, at a thickness of ice of 1½ inches, individual soldiers are spaced 20 paces at a minimum. (frame 7-50 and panel 7-9)

18. Two general categories of landing mats have been established, one for medium duty and one for light duty. Each is capable of sustaining 200 coverages of a 25,000-pound single wheel load with tire pressure of 250 pounds per square inch. The medium duty mat can be placed over a subgrade with a CBR as low as 4. (frame 7-53 and panel 7-10).

19. Portable surfaces for airfields fall into two principal classes — the **landing mat** and **nylon membrane.** Landing mats are designed to provide a structural load distributing media and wearing surface. Nylon membranes are intended only to protect otherwise structurally adequate surfaces from changing character in wet weather and to eliminate dust. (frame 7-52 and panel 7-55)

20. Bituminous materials are commonly used as dust palliatives. Chemical agents such as calcium chloride ($CaCl_2$) have also been used with success. However, $CaCl_2$ is generally not used on airfields because of its corrosive effect on aircraft. (frame 7-59)

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