PRELIMINARY TIME ESTIMATES

FOR CORING OPERATIONS

Ocean Drilling Program

Texas A&M University

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Philip D. Rabinowitz
Director

Louis E. Garrison
Deputy Director

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I. INTRODUCTION

This revision of ODP Technical Note No. 1 has been undertaken to document the reality of operational time requirements aboard JOIDES Resolution as they apply to the planning of future ODP expeditions. The original Technical Note No. 1 was published before ODP operations began and was based upon experience of the final two years of the Deep Sea Drilling Project with the GLOMAR CHALLENGER drillship. The drill string and wireline trip time curves in this revision reflect actual operating times recorded on seven recent ODP legs. The time estimates for logging operations are derived from the experience of the ODP Borehole Research Group and projected requirements for equipment and techniques currently under development.

The purpose of Technical Note No. 1 is to assist scientific planners in "fitting" the number and type of drill sites to the time available for a given voyage. Because of the complexity of ODP operations and the existence of various unpredictable factors, this guide should not be relied upon for detailed operational planning. Once a site has been approved and its objectives have been defined, detailed planning should proceed only in consultation with the ODP Drilling Operations Group, Science Operations Group, and Borehole Research Group. The optimum coring mode, need for reentry, number of holes required, logging program, etc., can then be determined along with a more accurate time estimation.

II. TRIP-TIME GRAPHS

Figures 1-4 are modifications of graphs used in the original version of this publication. They may be used for estimating operating time in both single-bit and reentry holes.

Data from ODP Legs 103, 104, 105, 107 and 108 were compiled. (Legs 100-102 were considered to be 'learning curve' legs, while Legs 106 and 109 were not representative of routine operations.) Each data point is marked by the third digit of its leg number. The solid line denotes the revised curve and the dashed line represents the curve used in the original version.

Figure 1: Drill String Round Trip: The curve represents total time, from beginning to make up the bottom-hole assembly (BHA) to commencement of coring operations, plus the time from starting off total depth until the BHA is racked. It includes minor delays, shipping of drilling line, handling of the top drive and guide horn and other activities attendant to tripping. No significant breakdowns or major delays (over 1/2 hour) are included. Note that the curve is expected to depart from a straight line with depth due to lower drawworks gearing for heavy strings.

Figure 2: Rotary Coring (RCB) Round Trip: Each data point is the average time for a complete coring cycle over an uninterrupted sequence of three or more cores, less the recorded rotating time for those cores. No extra wireline trips or other delays are included.

Figure 3: Advanced Piston Corer (APC) Round Trip: As there is theoretically no rotating time involved in piston-coring operations, the data points show complete coring cycle times. Time spent on orientation and temperature measurements is included. That accounts for some of the point scatter, as well as stiff sediment that consumed extra time in "drilling down the shoulder," which is normally concurrent with the wireline trip. In this case the revised curve is coincident with the previous one.

Figure 4: Extended Core Barrel (XCB) Round Trip: This curve was generated in exactly the same manner as Figure 2. Note that the XCB was still in the developmental stage at the inception of the ODP and that the same dashed curve is used for RCB and XCB.

Data used in the curves were compiled by Lamar Hayes and Glen Foss. The graphs were plotted and drafted by Eric Schulte and Steven White.

III. PRELIMINARY TIME ESTIMATES FOR DRILLING OPERATIONS, SINGLE-BIT HOLES

Many ODP sites can still be investigated with a single borehole, but the increasing diversity and specialization of operations often dictate that two or more holes must be drilled. The compatibility of the APC and XCB systems now permits high-quality piston cores in the unconsolidated section with rotary (XCB) cores into moderately indurated sediments at intermediate depths (usually 600-800 m) in a single hole. If any amount of rock is to be cored, however, it is necessary to make a round trip of the drill string for a RCB BHA.

Operating time on a single-bit hole may be estimated through four basic steps:

1. Estimate one drill string round trip (ARTT) from Figure 1. Use average depth or $\frac{\text{water depth + total depth}}{2}$.

2. Determine rotating hours (RH):

$$RH = \frac{\text{interval length cored}}{\text{average penetration rate}}.$$

3. Determine wireline time (WT) for the interval to be cored:

$$WT = \frac{\text{interval length cored}}{9.5 \text{ m/core}} \times \text{average wireline trip time.}$$

   For wireline trip time, enter the applicable graph (Figs. 2, 3 or 4) with the depth to the center of the cored interval (that is, the average depth of the entire cored interval). To cover the predictable occurrence of minor delays, one extra wireline trip for each 20-30 cores is normally included.

4. Determine time for logging operations using Section VI, along with information on the downhole instrumentation program as provided by the ODP Borehole Research Group and other investigators.

Note that the above steps produce a minimum time on site and do not include such operations as positioning the ship, flushing and conditioning the hole, instrument probe runs, hole surveys, filling or plugging the hole, fighting unstable hole conditions, etc., which occur on an "as-required" basis. "Unpredictables," such as a major breakdown, lost holes and weather/ice delays obviously occur but are impossible to factor into the planning process with any degree of validity.

IV. PRELIMINARY TIME ESTIMATES FOR DRILLING OPERATIONS, MULTIPLE-BIT/REENTRY HOLES

Reentry Site Time Estimation

Time for reentry operations can be estimated using the graphs provided and the information included on reentry site times and penetration rates. (Data from previously drilled sites in the areas of interest should be used if available.) The following section includes the estimated times for setting reentry cones and casing.

Time Estimating Procedures, Reentry Operations

The following step-by-step procedure may be used for preparing the time estimate:

1. Estimate the time for an exploratory hole to 800 meters using Section III.

2. Estimate times for setting reentry cone and 16-inch casing. Individual operations and times are:
   (a) One round trip of drill pipe for cone/casing assembly (Fig. 1).
   (b) Deploy reentry cone - 4 hours.
   (c) Making up casing string - 25 minutes per 12-meter joint of casing. Calculate total time for make-up and add 3 hours to total time.
   (d) Jet in 16-inch casing and release.
   (e) Drilling ('washing') time for interval of exploratory hole previously drilled. Typically, the above operation (a) through (e) requires 2-1/2 days.

3. If an additional 11-3/4 inch casing string is needed, the added operations are:
   (a) Round trip and reentry for casing (Figs. 1 and 5).
   (b) Making up 11-3/4 inch casing string - allow 20 minutes per 12 meter joint and add 2 hours to total.
   (c) Land and cement casing - 3 hours.
   (d) Round trip and reentry for core bit.
   (e) Drill out cement, plug, and shoe.

   Items (a) through (e) typically require 4 days. Thus the total time for a dual casing string operation is the sum of the time for items b and c or a total of 6 1/2 days before coring commences below the depth reached in the exploratory hole. (An 11-3/4 inch casing string may be required to prevent hole caving in rubble zones or to prevent erosion of the upper softer sediments during subsequent drilling operations.)

4. Figure 5 indicates time for wireline/scanning sonar reentry. (Total time for TV reentry operations is currently equivalent to that of sonar reentries but is expected to be less with future operational improvements.)

5. Estimate time to core sedimentary section below 800 meters. Use penetration data from other sites in area if available. Refer to page 7 for comments on penetration rate estimating. For indurated claystone, limestone, and cherty chalks, an average of 60 minutes per 9.5 meters is appropriate. Soft chalks core at about 12 minutes per core (38 m/hour).

   Determine rotating hours (RH):

$$RH = \frac{\text{interval length cored}}{\text{average penetration rate}} .$$

6. Determine wireline time (WT) for the interval to be cored by determining the number of cores x average wireline time per core:

$$WT = \frac{\text{interval length cored}}{9.5 \text{ m/core}} \times \text{average wireline trip time.}$$
(from Fig. 2)

7. Determine the total drill string round trip time (DSRT) for the interval to be cored:

$$DSRT = \frac{RH}{55} \times ARTT.$$

   A more accurate method is to add individual round trips based on their specific total depths and to make allowances for slower pipe speed in open hole.
   Where RH = rotating hours from item 5 above, 55 hours = average bit life (sedimentary section), and ARTT = average drill pipe round trip time (Fig. 1).
   Figure 1 provides drill string round trip (ARTT) (two way) time as a function of depth.

8. Determine total time for reentry scanning, rigging, and wireline time from Figure 5.

9. Determine time for logging operations using Section VI, along with information on the downhole instrumentation as provided by the ODP Borehole Research Group and other investigators.

The above procedure provides an estimate of time to core and log the sedimentary interval. A similar approach is used for a basalt interval except that the bit life used is 35 hours and the average rate of penetration is estimated at 2-1/2 meters/hour. (In hard, dense basalts, rates have dropped to 1 meter/hour.)

The total hole time then is the sum of:

Exploratory hole time.
Reentry cone setting time (single and possibly dual casing).
Rotating hours (actual drilling and coring time on bottom).
Wireline trip time to recover core - total time.
Drill string round trip time based on total number of trips.
Wireline reentry operations time.
Logging operations time.

Allowances have not been made for hole or weather problems or other contingencies.

V. PENETRATION RATE ESTIMATING

Actual rotary drilling rates in sedimentary material vary from about 120 m/hr in soft ooze and clay to about 2-3 m/hr in hard limestone. Note that indurated clay coring rates can be even slower than those of hard rock if bit teeth or inserts are too short.

Rates in basalt range from 10-12 m/hr in vesicular, fractured or glassy material to 1-2 m/hr in dense unfractured rock. About 2-1/2 m/hr is generally used for planning.

Drilling (preferred term instead of "washing") rates differ from coring in that higher circulation rates can produce up to 100% faster penetration in the upper (softer) section. Also, connection time of 5 minutes per joint must be added to rotating time for drilling ahead. (This is included in wireline trip time for coring.) Drilling becomes slower than coring in indurated material. Bit hydraulics no longer destroy the core, and the core barrel fills up. The point is eventually reached where continuous coring is the more efficient mode of penetration.

Rotating bit life (to destruction) may be over 100 hours in single-bit sediment holes, but is generally only about 40 hours in basalt. To avoid under-gauge hole or junk in reentry holes, bits are not normally run beyond 50-60 hours in sediments and 30-35 hours in basalt.

VI. LOGGING TIME ESTIMATES

Total logging time at any site includes not only the time for collecting data but also time for hole preparation, logging tool rigup, and other logging-related activities. Based on previous ODP logging operations, most aspects of logging can be estimated with reasonably good accuracy. Total logging time depends primarily on four variables: the tools to be run, whether or not the sidewall entry sub (SES) is used, water depth, and sub-bottom penetration depth of the hole.

Table 1 shows the logging tools that are routinely available on JOIDES Resolution. The first twelve log types in Table 1 are Schlumberger logs run by the Schlumberger engineer. The last two logs are ODP specialty logs run by the LDGO Logging Scientist. In order to save logging time, many of the tools are run together in tool combination strings (Table 1). The seismic stratigraphic combination includes the sonic, three resistivity, gamma ray, and caliper tools. The lithoporosity combination includes the neutron (Am/Be source), density, and spectral gamma ray tools. The geochemical combination includes the spectral gamma ray, gamma spectroscopy, and aluminum clay (neutron porosity) tools.

As shown in Table 1, the geochemical combination is the only tool string that collects useful data through drill pipe. Even data from the geochemical combination are more accurate if collected open-hole, i.e., in a previously drilled interval from which the pipe has been withdrawn. Normally, pipe is pulled to a depth of 50-100 mbsf. Variations from the 75-mbsf assumption cause very minor changes to total logging time.

The seismic stratigraphic and geochemical combinations are two "standard" Schlumberger logs that are run at virtually every logged hole. Table 2 lists all logging operations times involved in hole preparation and running these two Schlumberger combinations. The lithoporosity combination is the third of the Schlumberger strings that are important at nearly all logged sites. Logging times for the lithoporosity combination are shown in Table 3. Table 3 also lists the additional times required to run the borehole televiewer, multichannel sonic, or dual laterolog. Note that these times for the four tools assume that the "standard" Schlumberger logs of Table 2 have been run, so Table 3 does not include hole preparation and general rigup/rigdown times that are already included in Table 2. Most times in Tables 2 and 3 are functions of either pipe length or open-hole length and of either tool speed or pipe pulling speed. For example, the time to run the tool down to base of pipe when using the SES (Table 2) is (WD+75)/2200, i.e., a distance equal to water depth plus 75 m at a speed of 2200 m/hour.

Prior to Leg 112, the major uncertainty in logging time estimates involved delays associated with bridges. A bridge is a constricted hole interval that the logging tool may not be able to get past, while the tool is on its way down through open hole. Nearly all ODP bridges are found in sedimentary sequences and are caused by clay swelling after drilling. Bridges can also form in heavily fractured formations, but these have been much rarer. Deep basalt holes virtually never exhibit bridging. Bridging is very difficult to predict before a leg begins. Even after drilling and before logging, the likelihood of bridges cannot always be estimated reliably.

If a bridge is encountered that stops the logging tool, one has two choices. First, one can just log the interval above the bridge and cancel plans to log beneath the bridge. Second, one can pull the logging tool out of the hole and up onto the ship, set pipe through the bridge, then lower the logging tool again. Nearly always, the much heavier drill pipe can punch through bridges that stopped the lighter logging tool. This second option requires about 3-4 hours for each bridge, in addition to the logging times shown in Tables 2 and 3 in the column "Time, no SES."

To date, more than half of the ODP sediment holes have encountered bridges. To prevent lost time or lost logs associated with bridges, JOIDES Resolution now has the capability of using a sidewall entry sub (SES) during logging. The SES was tested successfully on Leg 108, modified, and will be routinely used for the first time on Leg 112. The SES, when inserted into the drill string, allows one to add or remove drill pipe while a logging tool is downhole. The SES strategy is to lower pipe to near the bottom of the hole, lower the logging tool into open hole just beneath the pipe, then log up while simultaneously pulling pipe at the same speed. In this way, open-hole logs are obtained without allowing enough time between pipe removal and logging for bridges to form. We emphasize that the SES is just starting routine usage, so that logging time estimates with the SES are still uncertain. Nevertheless, available information suggests that the most appropriate planning approach is to assume the SES will be used. If the SES is planned for but not needed, logging operations will take 1-12 hours less than planned at a site. Tables 2 and 3 include separate logging time estimates for programs with and without the SES.

In order to estimate the logging time for a site, it is not necessary to use Tables 2 and 3. The times required for many steps for each logging run can be combined into a single equation. Table 4 lists these equations derived from Tables 2 and 3. To estimate total logging time for a site, simply

1) decide whether or not the SES is likely to be used (probably yes);
2) calculate the total logging time for each logging tool (or tool string) planned, by inputting water depth and sub-bottom depth of penetration into the equation for that tool; and
3) add the times for the various runs.

For example, suppose the "standard" Schlumberger (seismic stratigraphic and geochemical combinations) and lithoporosity combination tool strings are to be run at a site in 3000 m water depth, with 1000 m sub-bottom penetration. The SES will be used. The time for hole preparation and running the "standard" Schlumberger logs is

$$11.7 + 0.0018 \times 3000 + 0.0145 \times 1000 = 32 \text{ hours.}$$

The additional time for the lithoporosity combo is

$$1.6 + 0.0009 \times 3000 + 0.0058 \times 1000 = 10 \text{ hours.}$$

Thus, all logging operations at this site require less than two days and obtain nine of the twelve logs shown in Table 1, or about 30 different types of log curves.

Table 4, as well as Tables 2 and 3, assumes that the entire interval below 75 mbsf is logged, except for the cases of the geochemical combination (included in "standard" Schlumberger) and borehole televiewer. The times for the geochemical combination include not only the open-hole interval but also two logging passes through pipe for the uppermost 75 mbsf. The borehole televiewer is the slowest of the tools and the only tool that is sometimes run over only part of the hole. Thus, the equation for this tool includes a third variable: length of interval to be logged.

The logging time equations in Table 4 are good working estimates, but they do not include four contingencies:

1) time required to punch through bridges or change to the SES if logging starts without the SES;
2) for reentry holes in which it is not permissible to drop the bit at the bottom of the hole, time to pull the drill string, remove the bit, and reenter the hole;
3) time beyond one hour to drop the bit, due to problems with the bit release; and
4) tool or cable breakdown, which occurs at about 10% of sites and requires 1-3 hours extra to deploy a backup tool or cut off faulty cable.

The preceding discussions of logging times consider all logging tools that are routinely available aboard JOIDES Resolution. For individual legs, scientists may bring their own logging tools (e.g., magnetometer, vertical seismic profile tool). Estimation of logging times for these tools requires consultation with these scientists.

TABLE 1. SHIPBOARD LOGGING TOOLS AND THEIR APPLICATIONS

LOG	ACRONYM	PRINCIPLE	USABLE THROUGH PIPE	COMBINABLE	APPLICATION*: SEISMOGRAM/ SYNTHETIC**	LITHOLOGY & MINERALOGY***	POROSITY	GEOCHEMISTRY (# ELEMENTS)	OTHER
Sonic	LSS	travel time of sound (2 receivers)	N	X	G	F	G	-	
Resistivity									
-Shallow	SFL	resistivity to current	N	X	F	F	VG	-	
-Medium	ILM	induced current	N	X	F	F	VG	-	
-Deep	ILD	induced current	N	X	F	F	VG	-	
Gamma ray	GR	natural gamma-ray emissions	N	X	P	VG	-	-	
Caliper	CALI	hole diameter	N	X	-	P	-	-	#
Dual laterolog	DLL	resistivity to current	N	X	F	F	VG	-	
Neutron porosity (Am/Be source)	CNT-G	absorption of bombarding neutrons	Y	X	P	F	VG	1	
Spectral gamma ray	NGT	natural gamma-ray emissions	Y	X	P	VG	-	3	
Gamma spectroscopy	GST	capture of bombarding neutrons	Y	X	F	VG	F	6	
Density	LDT	absorption of bombarding gamma rays	N	X	G	G	G	-	
Neutron porosity (Cf source)	ACT	absorption of bombarding neutrons	Y	X	P	F	VG	2	
12-channel sonic	MCS	travel time of sound (12 receivers)	N	X	VG	F	G	-	##
Televiewer	BHTV	travel time + reflectivity of borehole wall	N	X	P	F	-	-	###

* usefulness of tool for application: VG=very good, G=good, F=fair, P=poor

** logs other than sonic and density are converted to pseudosonic or pseudodensity, based on known log responses to lithology and porosity

*** percentages of minerals with >3% abundance are determined from simultaneous inversion of several logs

\# quality control for other logs

\## shear velocity, apparent attenuation

\### stress directions, fracture orientations, structural dip, formation morphology

TABLE 2. LOGGING TIMES IN HOURS FOR "STANDARD" SCHLUMBERGER LOGS (SEISMIC STRATIGRAPHIC COMBINATION AND GEOCHEMICAL COMBINATION)

OPERATION	TIME USING SES	TIME, NO SES
Circulate mud	2	2
Wiper trip	-	1 + 2(SD-75)/667
Release bit	-	1
Pull up to 75 mbsf		1 + 2(SD-75)/667
Rig up (wireline heave comp., seis. strat. combo., poss. SES)	2-1/2	1-1/2
Run tool down to base of pipe	(WD + 75)/2200	(WD + 75)/3000
Log down to TD	-	(SD - 75)/1000
Lower pipe and tool to TD, reaming bridges	(SD - 75)/300	-
Release bit	1	-
Log up (while pulling pipe if SES)	(SD - 75)/500	(SD - 75)/600
Run tool up pipe to ship	(WD + 75)/2200	(WD + 75)/3000
Rig down seis. strat. combo., rig up geochem. combo.	2	1-1/2
Run tool down to open hole	(WD + 75)/2200	(WD + 75)/3000
Test and calibrate tool	1/2	1/2
Run tool down to TD	-	(SD - 75)/1000
Lower pipe and tool to TD	(SD - 75)/400	-
Log up (while pulling pipe if SES)	(SD - 75)/150	(SD - 75)/150
Log up through pipe	85/100	85/100
Move pipe 5 m, lower tool to open hole	1/2	1/2
Log up through pipe	85/100	85/100
Run tool up pipe to ship	(WD - 10)/2200	(WD - 10)/3000
Rig down (wireline heave comp., geochem. combo., poss. SES)	2-1/2	1-1/2

TD=total depth in meters, WD=water depth in m, SD=sub-bottom depth in m, SES=sidewall entry sub.
All time estimates in hours.

TABLE 3. LOGGING TIMES IN HOURS FOR OTHER LOGS
(BOREHOLE TELEVIEWER, MULTICHANNEL SONIC, DUAL LATEROLOG AND LITHOPOROSITY COMBINATION)

OPERATION	TIME USING SES	TIME, NO SES
Rig up tool	1	1
Run tool down to base of pipe	(WD + 75)/2200	(WD + 75)/3000
Run tool down to TD	-	(SD - 75)/1000
Lower pipe and tool to TD	(SD - 75)/400	-
Log up (while pulling pipe if SES):		
borehole televiewer	LI/90+(SD-75-LI)/500	LI/90+(SD-75-LI)/1500
or multichannel sonic	(SD - 75)/180	(SD - 75)/180
or lithoporosity combo.	(SD - 75)/300	(SD - 75)/300
or dual laterolog	(SD - 75)/500	(SD - 75)/1600
Run tool up pipe to ship	(WD + 75)/2200	(WD + 75)/3000
Rig down tool	1	1

TD=total depth in meters, WD=water depth in m, SD=sub-bottom depth in m, LI=length of interval to be logged in m, SES=sidewall entry sub.
All time estimates in hours.

TABLE 4. LOGGING TIME EQUATIONS

Using SES	
"Standard" Schlumberger	t = 11.7 + 0.0018 x WD + 0.0145 x SD
Lithoporosity Combination	t = 1.6 + 0.0009 x WD + 0.0058 x SD
Dual Laterolog	t = 1.7 + 0.0009 x WD + 0.0045 x SD
Multichannel Sonic	t = 1.5 + 0.0009 x WD + 0.0081 x SD
Borehole Televiewer	t = 1.7 + 0.0009 x WD + 0.0045 x SD + 0.0091 x LI
Without SES	
"Standard" Schlumberger	t = 11.2 + 0.0013 x WD + 0.0148 x SD
Lithoporosity Combination	t = 1.7 + 0.0007 x WD + 0.0043 x SD
Dual Laterolog	t = 1.9 + 0.0007 x WD + 0.0016 X SD
Multichannel Sonic	t = 1.6 + 0.0007 x WD + 0.0066 x SD
Borehole Televiewer	t = 1.9 + 0.0007 x WD + 0.0017 x SD + 0.0104 x LI

SES=sidewall entry sub, t=total logging time in hours, WD=water depth in meters, SD=sub-bottom depth in meters, LI=length of interval to be logged in meters.

FIGURE 1

DRILL STRING ROUND TRIP

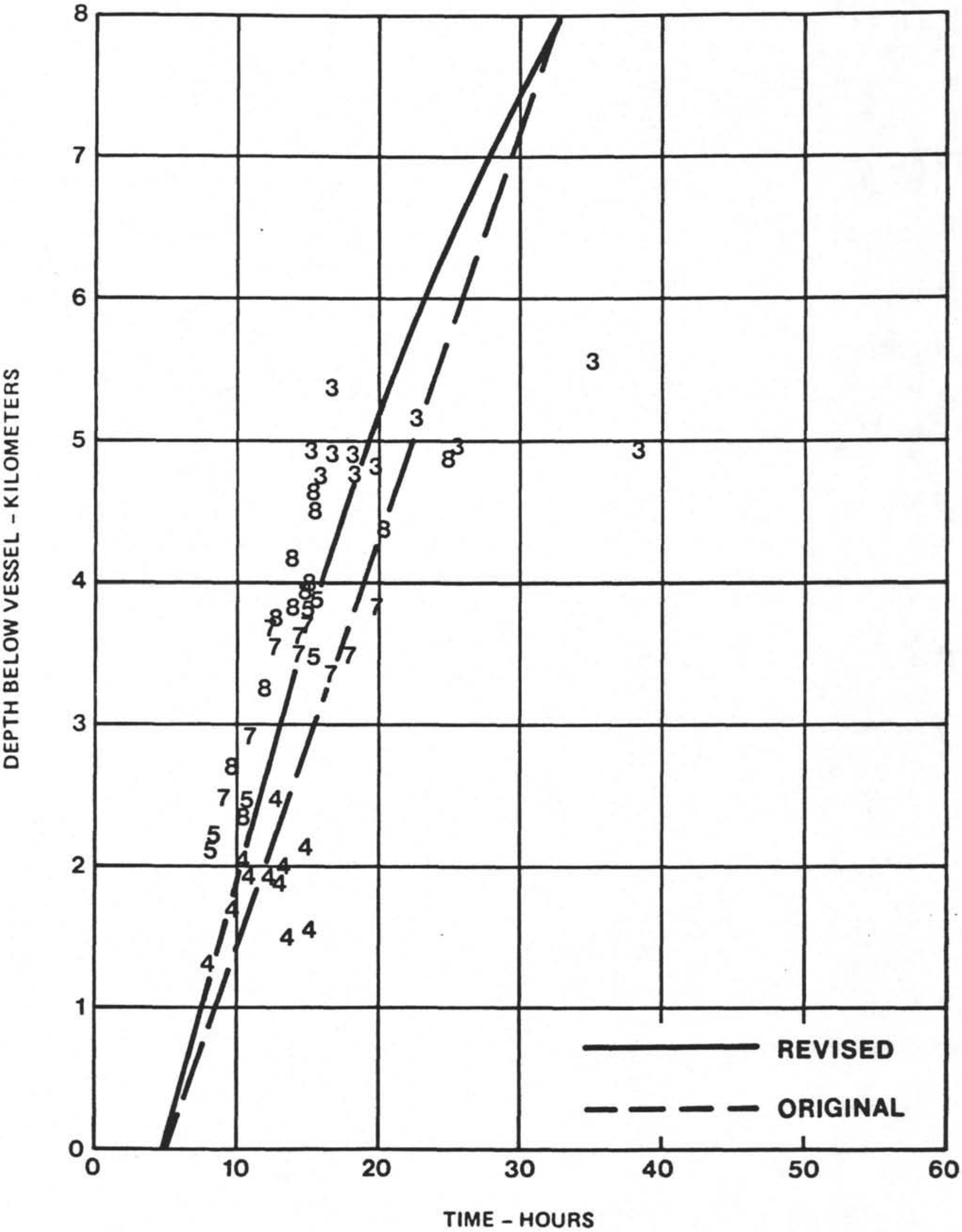
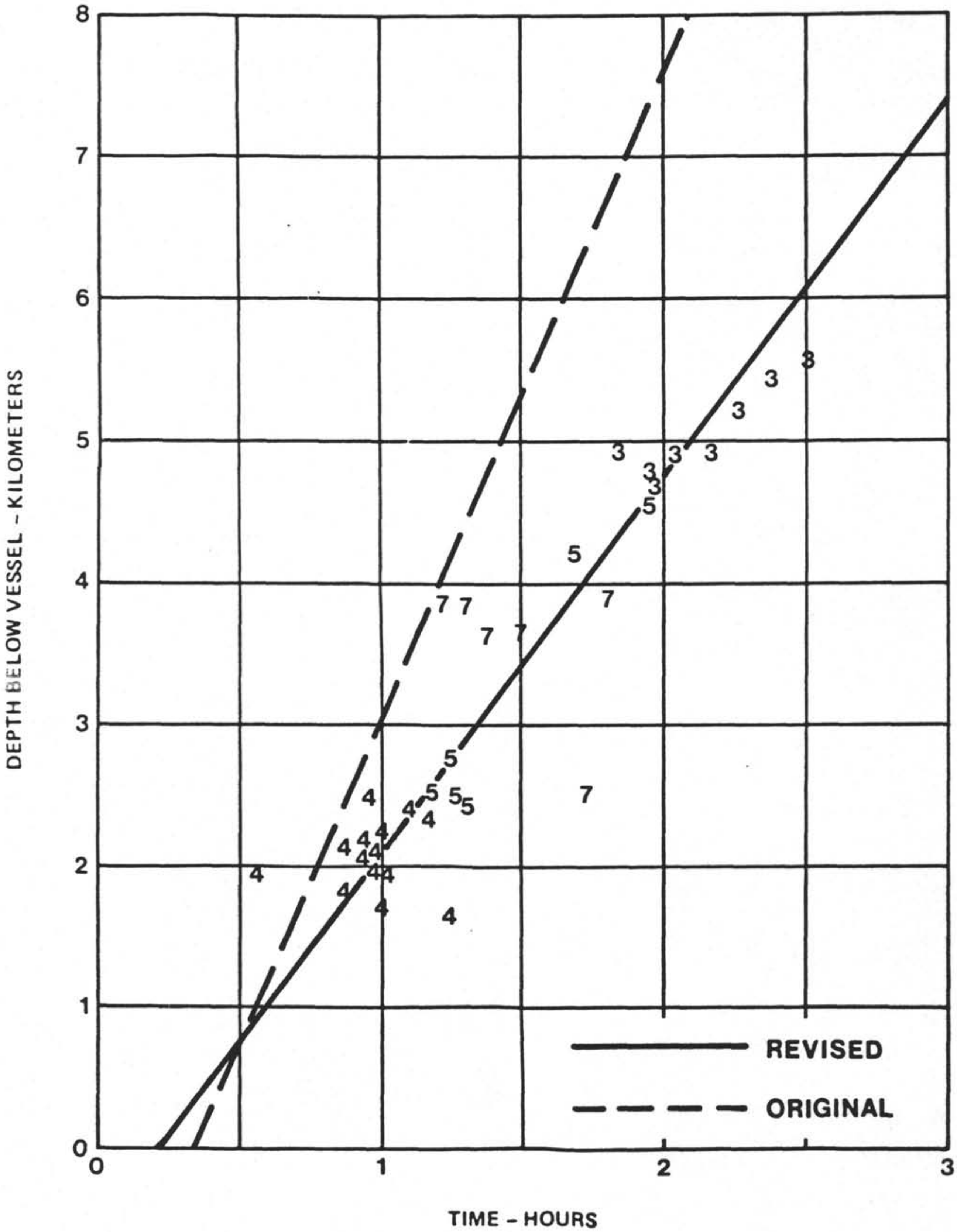


FIGURE 2

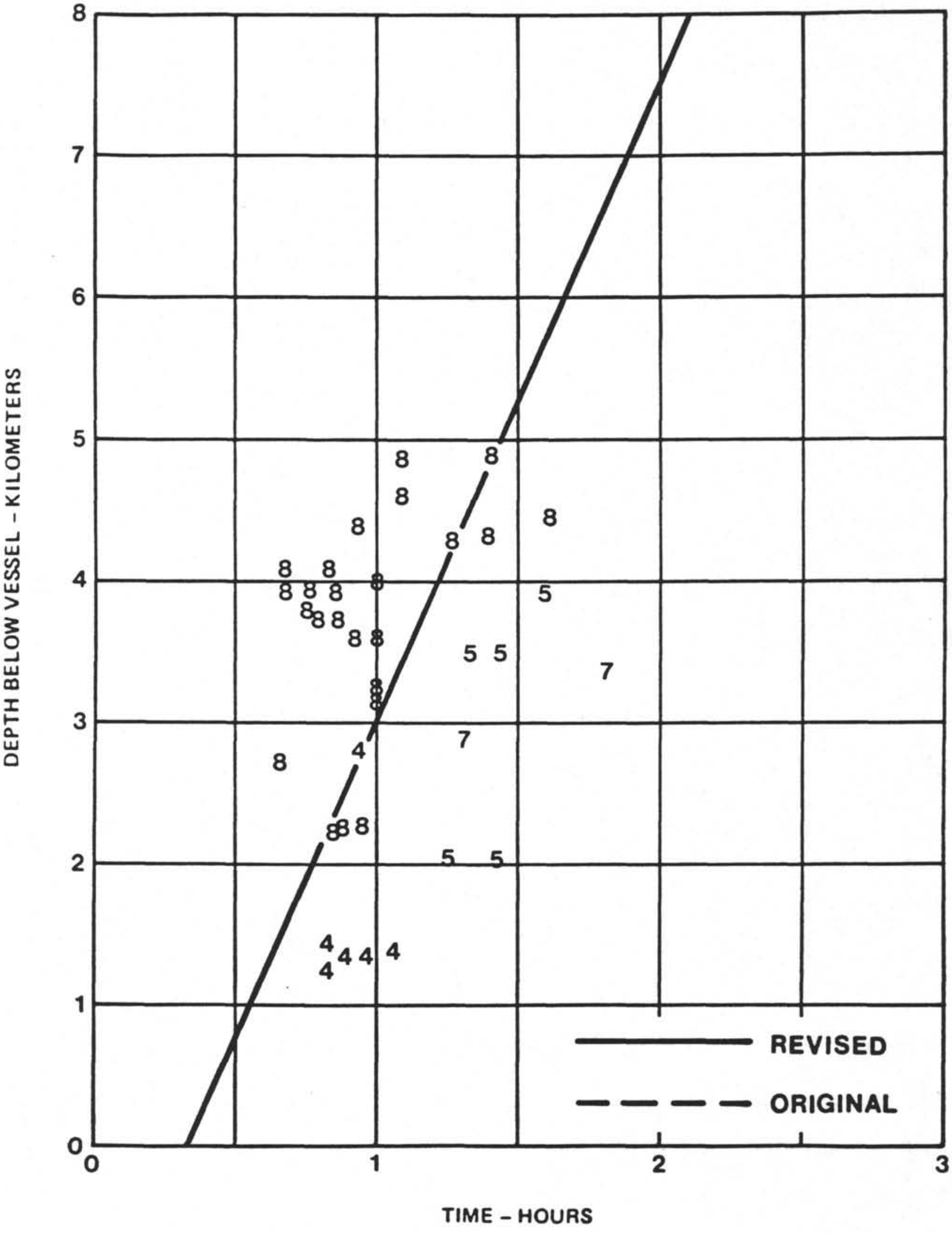
STANDARD ROTARY CORING (RCB) WIRELINE TRIP



(TOTAL TIME PER CORE CYCLE LESS ROTATING TIME)

FIGURE 3

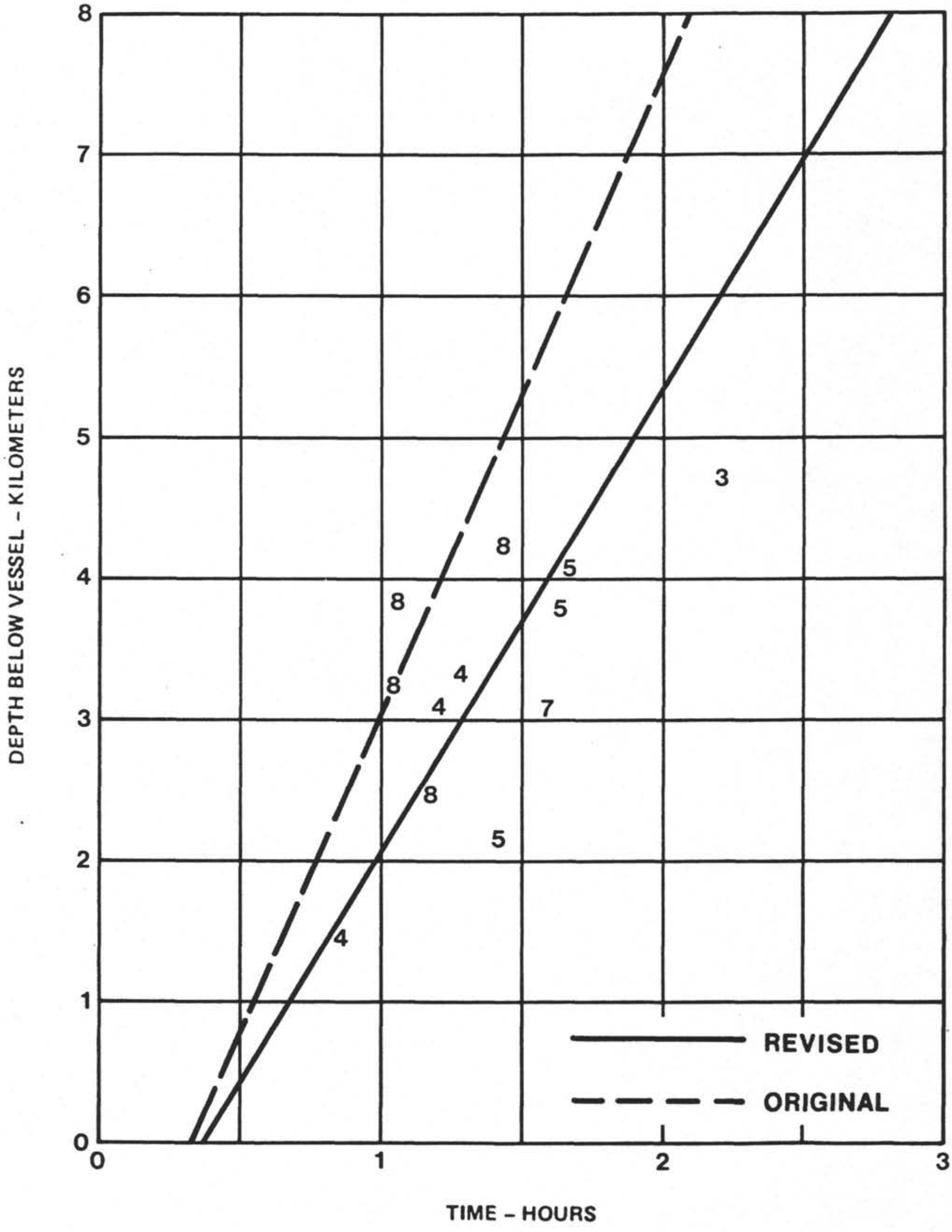
HYDRAULIC PISTON CORING (APC) WIRELINE TRIP



(TOTAL TIME PER CORE CYCLE)

FIGURE 4

EXTENDED CORE BARREL (XCB) CORING WIRELINE TRIP



(TOTAL TIME PER CORE CYCLE LESS ROTATING TIME)

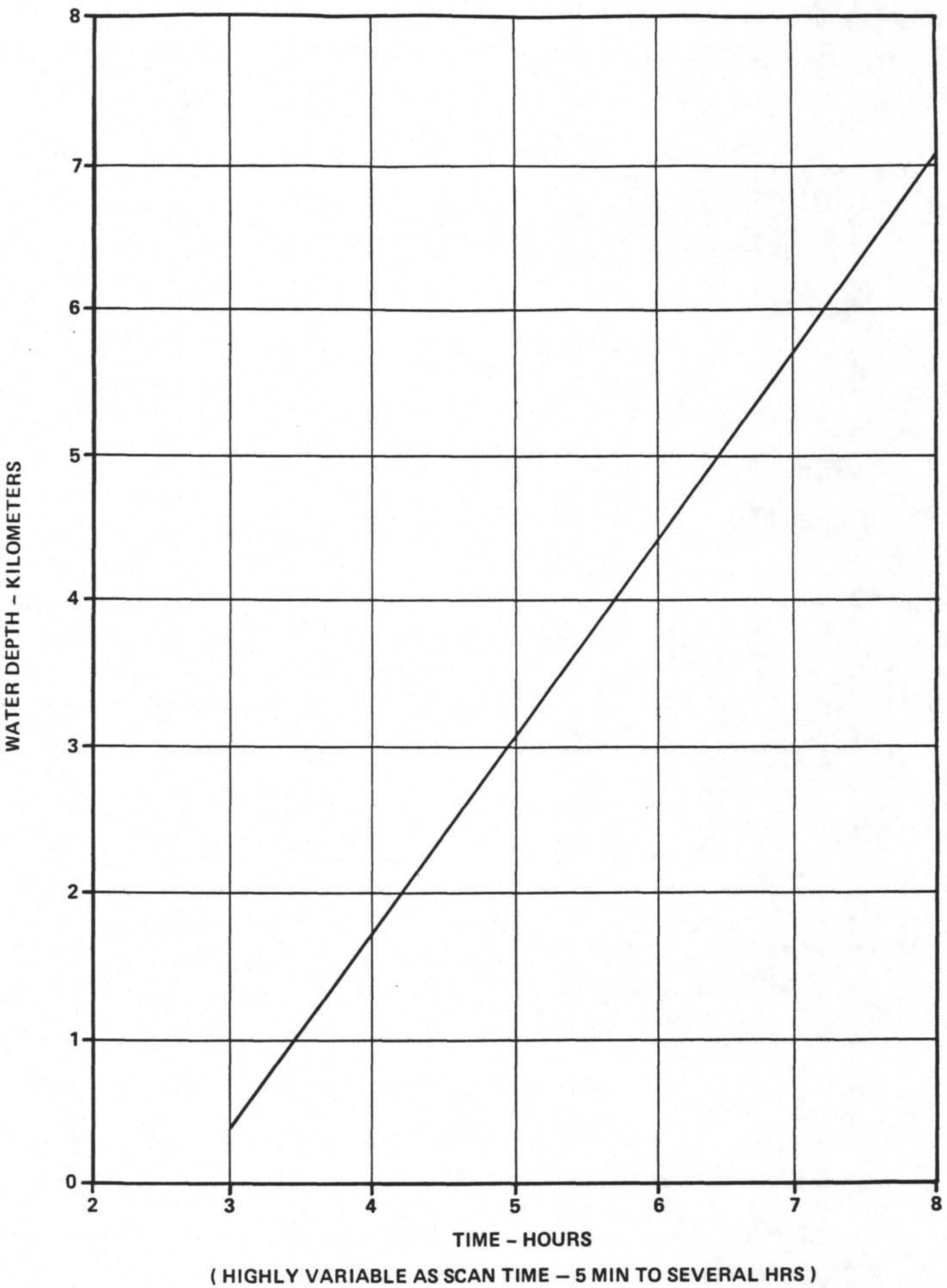


FIGURE 5. ESTIMATED RIGGING, WIRELINE, AND SCANNING TIME FOR REENTRY