Detailed Inspection of U.S. Army Railroad Trackage and Application to Civilian Short-Line Railroads

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The U.S. Army Construction Engineering Research Laboratory has developed a railroad track maintenance management decision support system called RAILER. The detailed track inspection procedures are designed to implement the recently issued Army Track Standards in a manner consistent with the larger goals of RAILER, thus promoting both track safety and track maintenance management. The inspection procedures are divided into six track component areas, and field inspection forms have been developed that guide the inspector through the inspection of each component area. The inspection procedures include measures for dealing with track components that are hidden, such as by vegetation or road crossings. In addition to the Army Track Standards, the inspection procedures can also support other track standards such as those propagated by the FRA or designed by a private operator. This property serves to facilitate a transfer to the civilian sector. The inspection procedures also take advantage of the RAILER computer software to ease the overall burden of the inspector.

RAILER is a decision support system for track maintenance management developed at the U.S. Army Construction Engineering Research Laboratory (USA-CERL) (*1*, *2*). It is currently being implemented at selected Army installations. Although primarily designed for Army use, RAILER was constructed to also facilitate technology transfer to the civilian sector for use by the commercial railroad community, especially short lines and industrial networks.

As a decision support tool, RAILER can be used, in part, to develop annual and long-range work plans, develop budgets, determine condition levels, and estimate maintenance and repair costs. RAILER uses personal computer-based software developed at USA-CERL to accomplish these tasks. The data base includes several information types, the most important of which are inventory and inspection. The inventory data elements are discussed in a paper by Uzarski et al. (*3*). The RAILER detailed inspection procedures are discussed here; a complete description of these procedures is presented in a USA-CERL technical report (*4*).

BACKGROUND

Commercial railroads are governed by the safety inspection requirements of the FRA (*5*). Individual railroad companies may also have their own inspection procedures for locating defects for maintenance planning. However, U.S. Army track networks do not fall under the auspices of the FRA, nor do Army track inspectors. Because of their varied duties and responsibilities, these Army track inspectors also do not have the same intimate knowledge of their networks as do track section foremen, track inspectors, and road masters in the commercial sector. Until recently, the Army's approach to track safety and track maintenance management was not very structured. Army track was divided into just two components for maintenance management—ties and trackage—and track inspection procedures were only generally described (*6*). Also, inspection intervals tended to be infrequent.

To facilitate efficient maintenance management of Army track and safe railroad operations, the Army has developed RAILER and issued detailed track maintenance standards (*7*). The standards serve the dual function of ensuring safety and identifying maintenance needs. The safety aspects are covered through the inspection frequency and the imposing of operating restrictions associated with certain defects. These operating restrictions are 10 mph, 5 mph, and "No Operations." Maintenance needs are determined through specific defect identification. Accordingly, the track standards provide a fundamental basis for track inspection and evaluation.

Many of the decision support tasks that RAILER is designed to perform require an assessment of track conditions, current and future. These conditions are determined by inspection with respect to the new Army Track Standards. While these standards are quite precise, they do not delineate specific inspection procedures. Such procedures were developed for RAILER. The inspection procedures outlined in this paper expand on and modify the previously documented interim detailed inspection procedures (*1*, *2*).

INSPECTION PROCEDURE CHARACTERISTICS

The RAILER detailed inspection procedures were developed primarily to fulfill two interrelated tasks. The first is to promote safe Army railroad operations by incorporating the technical aspects of the U.S. Army Track Standards into practical procedures. Second, the procedures provide a means for capturing the defect information in a format that facilitates

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use within the RAILER system for track maintenance management. The inspection procedures have the following characteristics:

- The inspection procedures are divided into component areas consistent with the Army Track Standards and the RAILER inventory data elements (*8*).
- Thorough detailed field inspection forms are used to guide the inspector through the inspection of each component area.
- Procedures are included for dealing with track components that are hidden, such as by vegetation or road crossings.
- Although the inspection procedures are designed to capture all discrepancies with the Army Track Standards, the procedures are at the same time flexible and thorough enough to support other track standards (such as those propagated by the FRA).
- The inspection procedures take advantage of the RAILER computer software to ease the burden of the inspector.

These interrelated characteristics are discussed more fully in the following subsections.

Inspection Component Areas

For convenience, the inspection procedures are divided into six track component areas:

1. Tie inspection;
2. Vegetation inspection;
3. Rail and joint inspection;
4. Other track components inspection;
5. Turnout inspection; and
6. Track geometry inspection.

The components included in "Other track components" are the bridge approach, ballast/subgrade, car bumper, car stop, culvert, ditch, derail, drain, embankment, grade crossing, gage rod, hold down device, insulated component, rail anchor, rail crossing, signals, signs, shim, spike, storm sewer, and tie plate.

The inspection procedures primarily consist of specific visual observations and manual measurements of the track structure, which may be augmented by automated data collection for track geometry and for rail and joint defects. A complete regular manual inspection would include the first five component areas; manual track geometry inspection is usually conducted only when there are specific indications of potential problems. (Examples of these indications include visual observations and reports of rough riding from the engine crew.)

The segmentation of the inspection process by component areas permits significant flexibility. For example, a track may be inspected for only one or two components, or all components, depending on the purpose of the inspection. This flexibility also allows the order in which component areas and track segments are inspected to be tailored for the particular network layout. Such an inspection plan is illustrated in Figure 1. For example, with a single isolated loading track, it may be advantageous to inspect some components in one direction and other components while walking back. However, with two parallel loading tracks, it may be better to inspect some or all components of one track in one direction and the same components of the other track while walking back.

Field Inspection Forms

The inspection process is organized around five field inspection forms. One of these forms deals with three component areas: ties, vegetation, and rail and joints. A completed example of this form is presented in Figure 2. An explanation of various categories in this figure is given as follows:

- In the column for Inspection Impaired by Vegetation or Other Material, the inspector has entered four lengths of track where tie inspection was impaired. The lengths were 10, 30, 70, and 25 ft, respectively. Addition (+) signs are used to separate the lengths. The lengths are then totaled below (135 ft).
- The various tie defects are delineated in the columns. Hash marks are used to note defects and then totaled.

Vegetation Inspection

Vegetation growth is noted in feet of affected track. Results of the vegetation inspection were as follows:

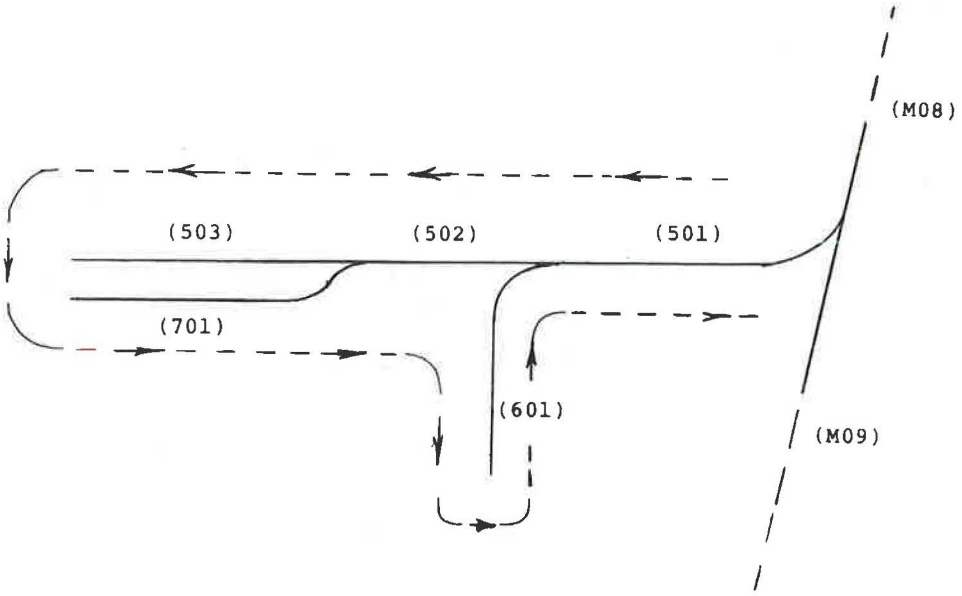
- There were four occurrences of low severity (Growing in Ballast, Interferes with Walking, etc.) vegetation growth. The occurrences were 10, 50, 20, and 200 ft in length, for a total of 280 ft.
- A 50-ft length of vegetation growth prevented track inspection.
- No vegetation growth serious enough to interfere with train movements was found.

Rail and Joint Inspection

Rail and joint inspection found the following defects:

- All bolts were loose (ABL) in a joint in the left rail at Station 1 + 00.
- The end batter (ENB) at joints was greater than ¼ in. in both rails starting at Station 1 + 00 and continuing over 10 joints.
- There was a broken or cracked joint bar (BCB) in the right rail at Station 2 + 20.
- Some joints had improper bolt pattern (IBP). Starting at Station 2 + 50 and continuing for 200 ft, about 50 percent of the joints had the improper pattern.
- Several lengths of inspection impairment were noted. Inspection was impaired for one quarter (one side of one rail) for an 8-ft length. For two-, three-, and four-quarters coverage, the lengths of impairment were 6, 8, and 4 ft, respectively. The line totals are then multiplied by the quarters of coverage to get the quarter lengths (Q.L.). The quarter lengths are then summed and divided by 4, which gives the equivalent length of complete inspection impairment.

These forms are designed to guide the inspector through a structured inspection process. This is especially well illustrated by the turnout inspection form (see Figure 3). Mastering the inspection procedure associated with using this form requires a minimal amount of training, despite the large amount of information that is collected. In this case, the four blocks



Inspection Plan for Tracks 5, 6, and 7

Segment	Component Areas
501	Ties and Other Track Components
502	Ties and Other Track Components
503	All Components
701	All Components
502	Vegetation and Rail and Joints
601	Ties and Other Track Components
601	Vegetation and Rail and Joints
501	Vegetation and Rail and Joints

FIGURE 1 Example of inspection plan.

on the form lead the inspector through the inspection; the inspector simply has to fill in the various blanks and circle the appropriate responses.

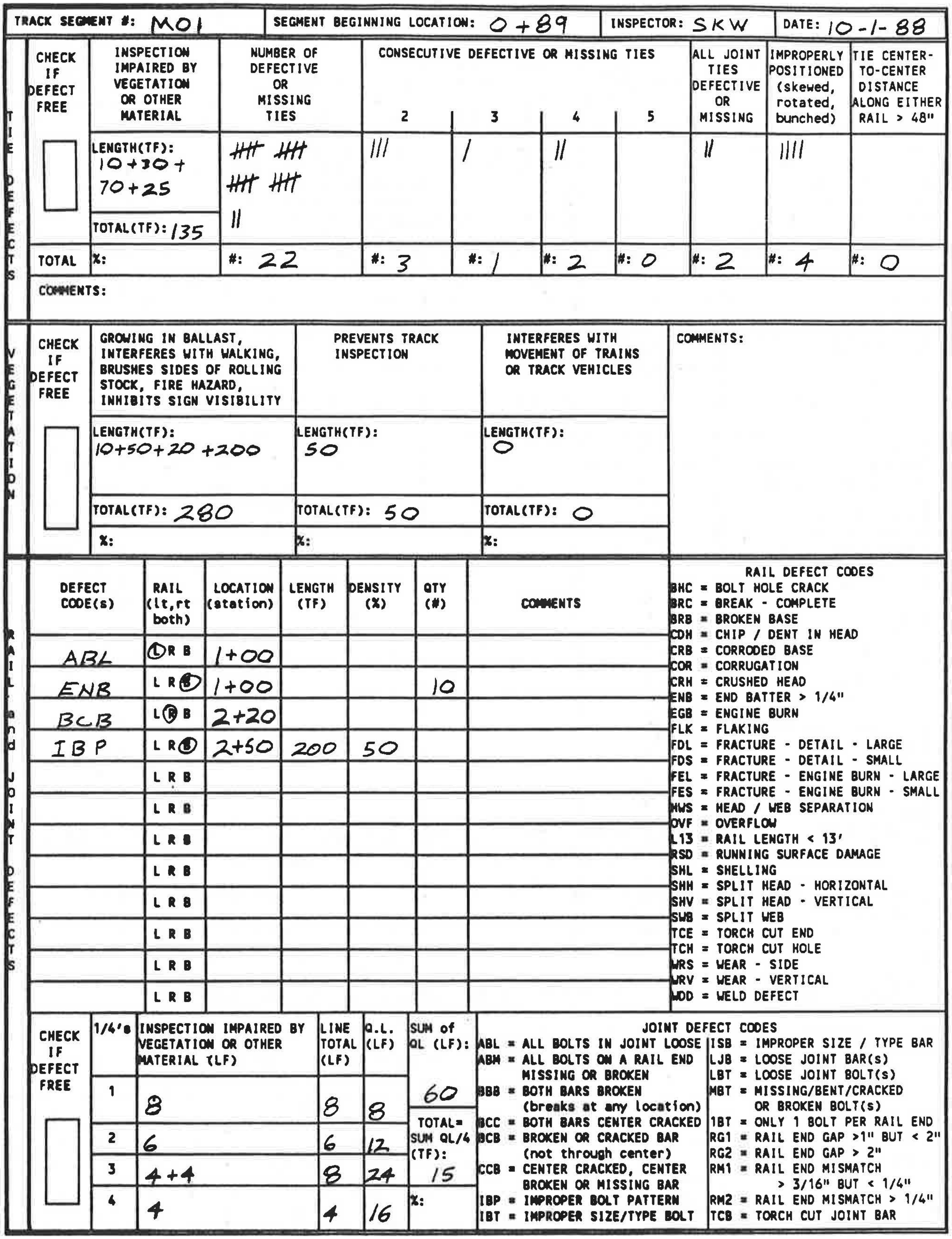
The other inspection forms are presented in an abbreviated fashion in Figures 4 through 6. The form depicted in Figure 4 can be used to continue the visual rail and joint inspection (see Figure 2) or for automated rail inspection. Because many rail defects are not visible (and hence can only be detected with specialized equipment), the continuation form depicted in Figure 4 lists more rail and joint defects than the form depicted in Figure 2. When used with automated rail inspection, the continuation form serves as a data transfer medium between the commercially prepared report (list of defects) and RAILER.

The track geometry inspection form (see Figure 5) is generally only used for manual inspection. Automatically collected track geometry data can be transferred directly from the geometry test equipment onto floppy disks for processing within the RAILER system. An explanation of segments of Figure 5 is given as follows.

- In Segment 101, Station 5+50, the gage is 57.8 in.
- In Segment 101, Station 7+00, the crosslevel is +1.5 in. (using the left rail as reference), the alignment is 0.5 in. in both the left and right rails, the profile of the left rail is 1.1 in., and the profile of the right rail is 0.5 in.
- In Segment 101, Station 7+05, the crosslevel is +0.5 in. (using the left rail as reference).
- In Segment 102, Station 9+00, the alignment of the left rail is 1.1 in., and the profile of the left rail is 1.5 in.
- In Segment 102, Station 10+50 (in Curve 1C1), the gage is 56.7 in., the crosslevel is +2.0 in. (using the left rail as the reference), the left alignment is 4.0 in., and the right alignment is 4.0 in.

Impaired Track Inspection

Sometimes grade crossings or material, such as excessive ballast and vegetation, will interfere with track inspection. This can be a particular problem where seldom used tracks may



TRACK SEGMENT #: MO1	SEGMENT BEGINNING LOCATION: 0+89	INSPECTOR: SKW	DATE: 10-1-88

TIE DEFECTS	CHECK IF DEFECT FREE	INSPECTION IMPAIRED BY VEGETATION OR OTHER MATERIAL	NUMBER OF DEFECTIVE OR MISSING TIES	CONSECUTIVE DEFECTIVE OR MISSING TIES				ALL JOINT TIES DEFECTIVE OR MISSING	IMPROPERLY POSITIONED (skewed, rotated, bunched)	TIE CENTER-TO-CENTER DISTANCE ALONG EITHER RAIL > 48"
				2	3	4	5			
	☐	LENGTH(TF): 10+30+70+25 TOTAL(TF): 135	𝍸 𝍸 𝍸 𝍸 𝍷𝍷	𝍷𝍷𝍷	𝍷	𝍷𝍷		𝍷𝍷	𝍷𝍷𝍷𝍷	
	TOTAL	%:	#: 22	#: 3	#: 1	#: 2	#: 0	#: 2	#: 4	#: 0
	COMMENTS:									

VEGETATION	CHECK IF DEFECT FREE	GROWING IN BALLAST, INTERFERES WITH WALKING, BRUSHES SIDES OF ROLLING STOCK, FIRE HAZARD, INHIBITS SIGN VISIBILITY	PREVENTS TRACK INSPECTION	INTERFERES WITH MOVEMENT OF TRAINS OR TRACK VEHICLES	COMMENTS:
	☐	LENGTH(TF): 10+50+20+200	LENGTH(TF): 50	LENGTH(TF): 0	
		TOTAL(TF): 280	TOTAL(TF): 50	TOTAL(TF): 0	
		%:	%:	%:	

RAIL and JOINT DEFECTS

DEFECT CODE(s)	RAIL (lt,rt both)	LOCATION (station)	LENGTH (TF)	DENSITY (%)	QTY (#)	COMMENTS
ABL	[✓ L] R B	1+00				
ENB	L R [✓ B]	1+00			10	
BCB	L [✓ R] B	2+20				
IBP	L R [✓ B]	2+50	200	50		
	L R B					
	L R B					
	L R B					
	L R B					
	L R B					
	L R B					
	L R B					
	L R B					

RAIL DEFECT CODES

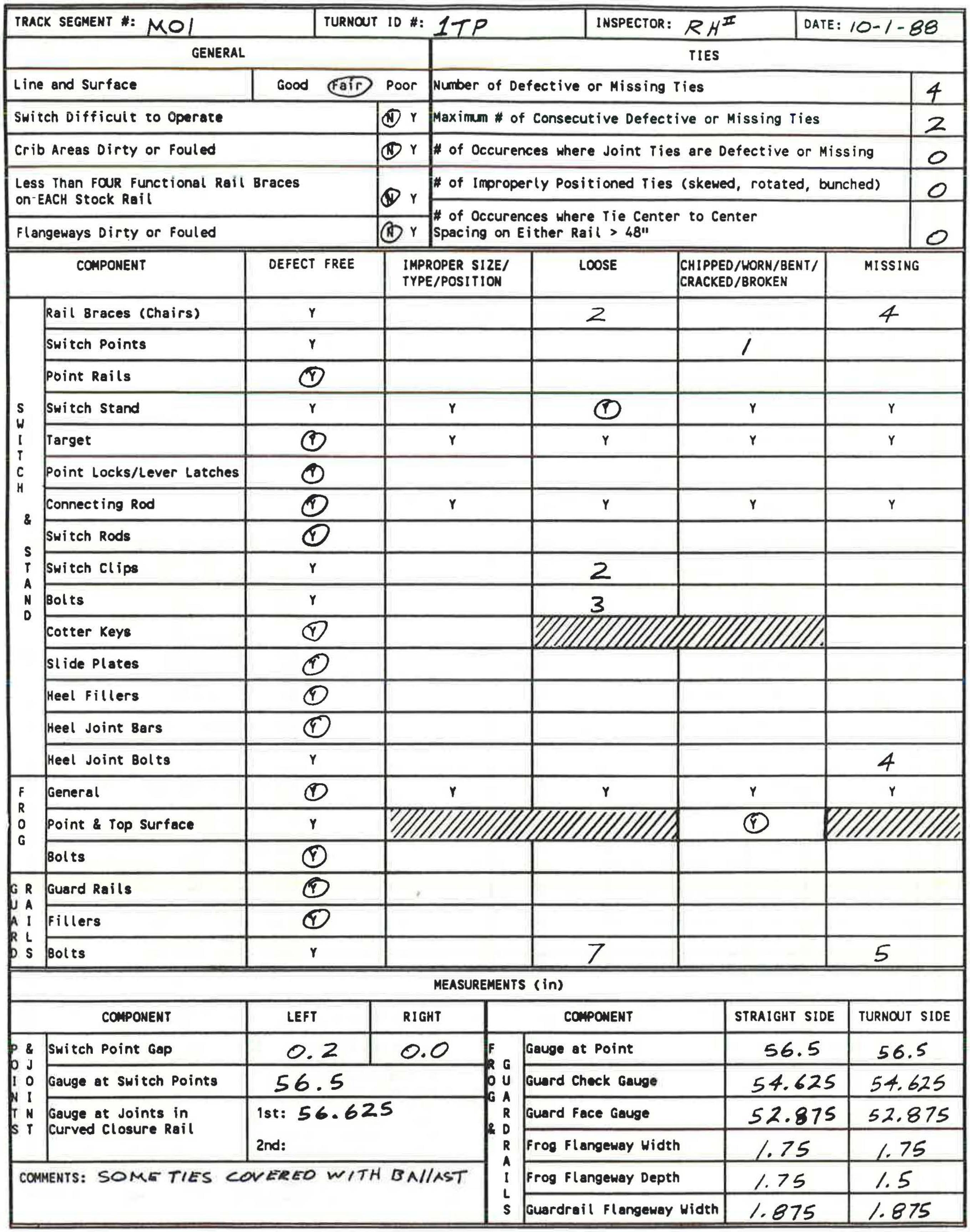
BHC = BOLT HOLE CRACK
BRC = BREAK - COMPLETE
BRB = BROKEN BASE
CDH = CHIP / DENT IN HEAD
CRB = CORRODED BASE
COR = CORRUGATION
CRH = CRUSHED HEAD
ENB = END BATTER > 1/4"
EGB = ENGINE BURN
FLK = FLAKING
FDL = FRACTURE - DETAIL - LARGE
FDS = FRACTURE - DETAIL - SMALL
FEL = FRACTURE - ENGINE BURN - LARGE
FES = FRACTURE - ENGINE BURN - SMALL
HWS = HEAD / WEB SEPARATION
OVF = OVERFLOW
L13 = RAIL LENGTH < 13'
RSD = RUNNING SURFACE DAMAGE
SHL = SHELLING
SHH = SPLIT HEAD - HORIZONTAL
SHV = SPLIT HEAD - VERTICAL
SWB = SPLIT WEB
TCE = TORCH CUT END
TCH = TORCH CUT HOLE
WRS = WEAR - SIDE
WRV = WEAR - VERTICAL
WDD = WELD DEFECT

CHECK IF DEFECT FREE	1/4's	INSPECTION IMPAIRED BY VEGETATION OR OTHER MATERIAL (LF)	LINE TOTAL (LF)	Q.L. (LF)	SUM of QL (LF): 60
☐	1	8	8	8	
	2	6	6	12	TOTAL= SUM QL/4 (TF): 15
	3	4+4	8	24	
	4	4	4	16	%:

JOINT DEFECT CODES

ABL = ALL BOLTS IN JOINT LOOSE
ABM = ALL BOLTS ON A RAIL END MISSING OR BROKEN
BBB = BOTH BARS BROKEN (breaks at any location)
BCC = BOTH BARS CENTER CRACKED
BCB = BROKEN OR CRACKED BAR (not through center)
CCB = CENTER CRACKED, CENTER BROKEN OR MISSING BAR
IBP = IMPROPER BOLT PATTERN
IBT = IMPROPER SIZE/TYPE BOLT
ISB = IMPROPER SIZE / TYPE BAR
LJB = LOOSE JOINT BAR(s)
LBT = LOOSE JOINT BOLT(s)
MBT = MISSING/BENT/CRACKED OR BROKEN BOLT(s)
1BT = ONLY 1 BOLT PER RAIL END
RG1 = RAIL END GAP >1" BUT < 2"
RG2 = RAIL END GAP > 2"
RM1 = RAIL END MISMATCH > 3/16" BUT < 1/4"
RM2 = RAIL END MISMATCH > 1/4"
TCB = TORCH CUT JOINT BAR

FIGURE 2 Completed inspection form for ties, vegetation, and rail and joints.



TRACK SEGMENT #: MOI	TURNOUT ID #: 1TP	INSPECTOR: RH^{II}	DATE: 10-1-88

GENERAL		TIES	
Line and Surface	Good [✓ Fair] Poor	Number of Defective or Missing Ties	4
Switch Difficult to Operate	[✓ N] Y	Maximum # of Consecutive Defective or Missing Ties	2
Crib Areas Dirty or Fouled	[✓ N] Y	# of Occurences where Joint Ties are Defective or Missing	0
Less Than FOUR Functional Rail Braces on EACH Stock Rail	[✓ N] Y	# of Improperly Positioned Ties (skewed, rotated, bunched)	0
Flangeways Dirty or Fouled	[✓ N] Y	# of Occurences where Tie Center to Center Spacing on Either Rail > 48"	0

	COMPONENT	DEFECT FREE	IMPROPER SIZE/ TYPE/POSITION	LOOSE	CHIPPED/WORN/BENT/ CRACKED/BROKEN	MISSING
SWITCH & STAND	Rail Braces (Chairs)	Y		2		4
	Switch Points	Y			1	
	Point Rails	[✓ Y]				
	Switch Stand	Y	Y	[✓ Y]	Y	Y
	Target	[✓ Y]	Y	Y	Y	Y
	Point Locks/Lever Latches	[✓ Y]				
	Connecting Rod	[✓ Y]	Y	Y	Y	Y
	Switch Rods	[✓ Y]				
	Switch Clips	Y		2		
	Bolts	Y		3		
	Cotter Keys	[✓ Y]		▨	▨	
	Slide Plates	[✓ Y]				
	Heel Fillers	[✓ Y]				
	Heel Joint Bars	[✓ Y]				
	Heel Joint Bolts	Y				4
FROG	General	[✓ Y]	Y	Y	Y	Y
	Point & Top Surface	Y	▨	▨	[✓ Y]	▨
	Bolts	[✓ Y]				
GUARD RAILS	Guard Rails	[✓ Y]				
	Fillers	[✓ Y]				
	Bolts	Y		7		5

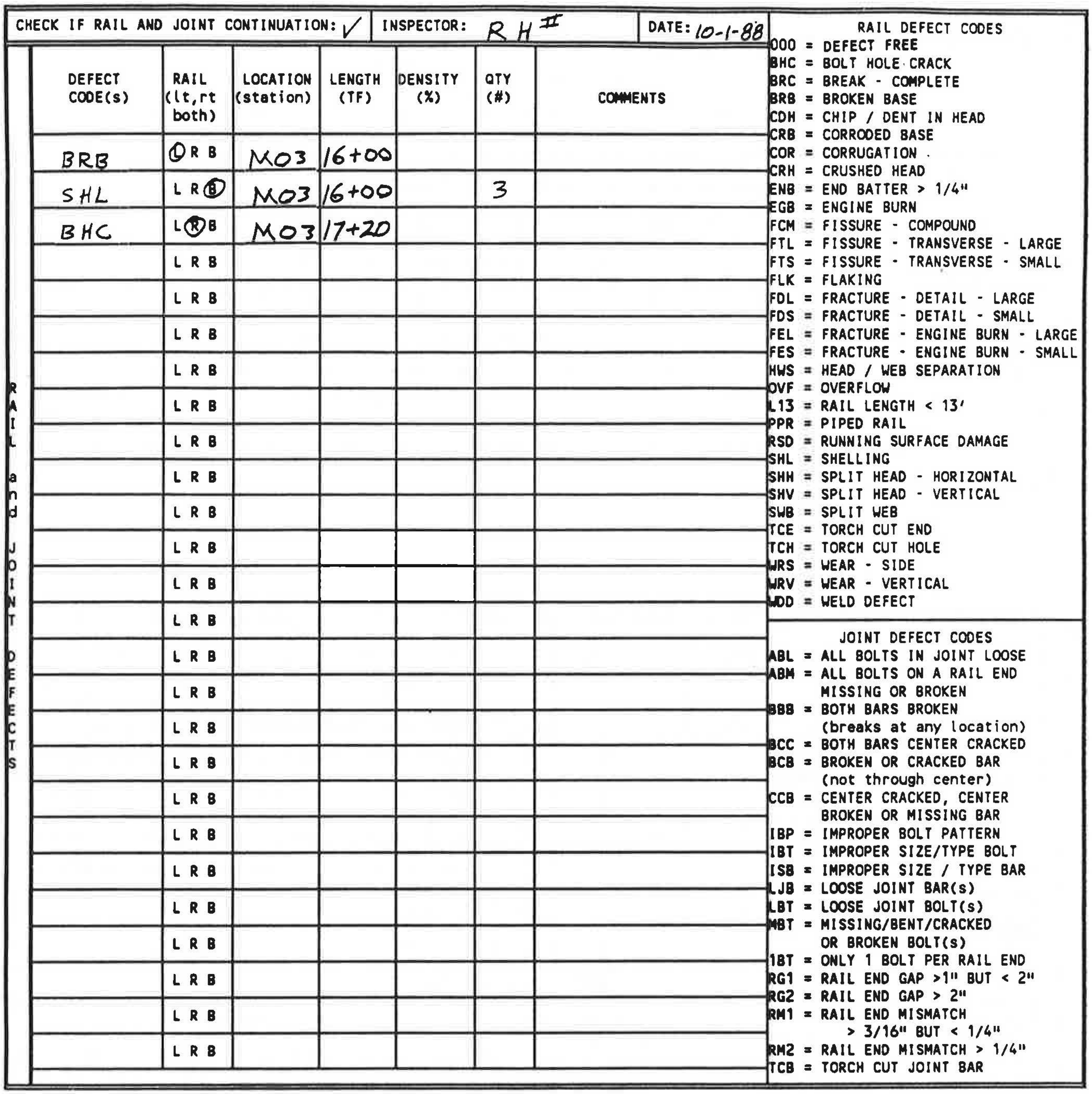
MEASUREMENTS (in)

	COMPONENT	LEFT	RIGHT
POINTS & JOINTS	Switch Point Gap	0.2	0.0
	Gauge at Switch Points	56.5	
	Gauge at Joints in Curved Closure Rail	1st: 56.625 2nd:	

	COMPONENT	STRAIGHT SIDE	TURNOUT SIDE
FROG & GUARDRAILS	Gauge at Point	56.5	56.5
	Guard Check Gauge	54.625	54.625
	Guard Face Gauge	52.875	52.875
	Frog Flangeway Width	1.75	1.75
	Frog Flangeway Depth	1.75	1.5
	Guardrail Flangeway Width	1.875	1.875

COMMENTS: SOME TIES COVERED WITH BALLAST

FIGURE 3 Completed turnout inspection form.



CHECK IF RAIL AND JOINT CONTINUATION: ✓ INSPECTOR: R H II DATE: 10-1-88

RAIL and JOINT DEFECTS

DEFECT CODE(s)	RAIL (lt,rt both)	LOCATION (station)	LENGTH (TF)	DENSITY (%)	QTY (#)	COMMENTS
BRB	[✓ L] R B	M03	16+00			
SHL	L R [✓ B]	M03	16+00		3	
BHC	L [✓ R] B	M03	17+20			
	L R B					
	L R B					
	L R B					
	L R B					
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CDH = CHIP / DENT IN HEAD
CRB = CORRODED BASE
COR = CORRUGATION
CRH = CRUSHED HEAD
ENB = END BATTER > 1/4"
EGB = ENGINE BURN
FCM = FISSURE - COMPOUND
FTL = FISSURE - TRANSVERSE - LARGE
FTS = FISSURE - TRANSVERSE - SMALL
FLK = FLAKING
FDL = FRACTURE - DETAIL - LARGE
FDS = FRACTURE - DETAIL - SMALL
FEL = FRACTURE - ENGINE BURN - LARGE
FES = FRACTURE - ENGINE BURN - SMALL
HWS = HEAD / WEB SEPARATION
OVF = OVERFLOW
L13 = RAIL LENGTH < 13'
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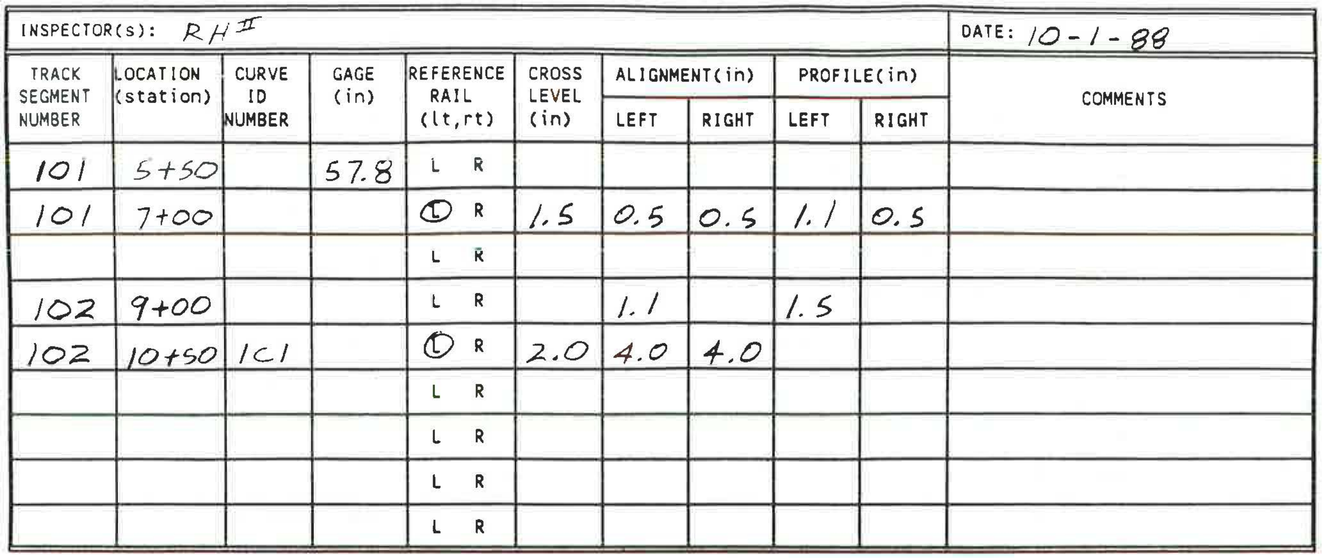
RM1 = RAIL END MISMATCH > 3/16" BUT < 1/4"
RM2 = RAIL END MISMATCH > 1/4"
TCB = TORCH CUT JOINT BAR

FIGURE 4 Completed rail and joint inspection continuation form.

be hidden by vegetation or other material and where significant track lengths may be paved (such as around warehouses and marshalling areas). If not properly accounted for, significant amounts of inspection-impaired track could cause profound overestimation of general track quality and consequent underestimation of necessary repair materials. This occurs when it is implicitly and erroneously assumed that defects not seen (and hence not recorded) do not exist. Furthermore, even a few linear feet of foreign material may hide serious defects affecting the safety of railroad operations.

Inspection-impaired track is accounted for separately within the RAILER detailed track inspection procedures for each of three component areas: ties, rail and joints, and other track components. These are separated for two reasons. First, foreign material that obscures one component might not impair the inspection of another component. For example, rail and joints can often be easily inspected when the ties are covered by ballast or soil. Second, the nature and extent of obscuring foreign material may change between the inspection of two component areas. For example, during the time between a tie inspection and an "other track components" inspection (which may be more than a month), gravel may have been accidentally spilled on the track, obscuring tie plates and spikes ("other track components").

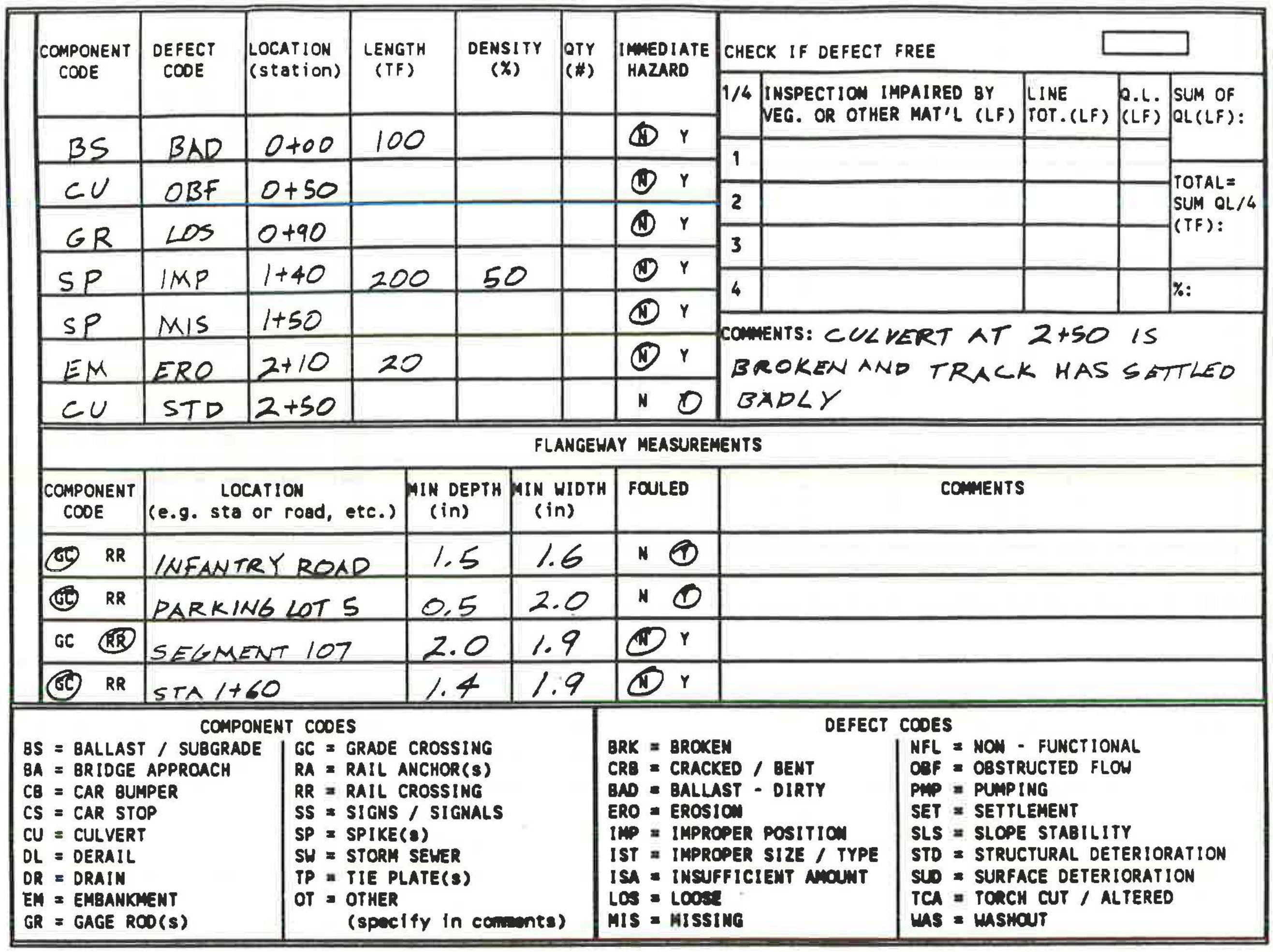


INSPECTOR(s): RH II

DATE: 10-1-88

TRACK SEGMENT NUMBER	LOCATION (station)	CURVE ID NUMBER	GAGE (in)	REFERENCE RAIL (lt,rt)	CROSS LEVEL (in)	ALIGNMENT(in)		PROFILE(in)		COMMENTS
						LEFT	RIGHT	LEFT	RIGHT	
101	5+50		57.8	L R						
101	7+00			[✓ L] R	1.5	0.5	0.5	1.1	0.5	
				L R						
102	9+00			L R		1.1		1.5		
102	10+50	1C1		[✓ L] R	2.0	4.0	4.0			
				L R						
				L R						
				L R						
				L R						

FIGURE 5 Completed track geometry inspection form.



COMPONENT CODE	DEFECT CODE	LOCATION (station)	LENGTH (TF)	DENSITY (%)	QTY (#)	IMMEDIATE HAZARD
BS	BAD	0+00	100			[✓ N] Y
CU	OBF	0+50				[✓ N] Y
GR	LOS	0+90				[✓ N] Y
SP	IMP	1+40	200	50		[✓ N] Y
SP	MIS	1+50				[✓ N] Y
EM	ERO	2+10	20			[✓ N] Y
CU	STD	2+50				N [✓ Y]

CHECK IF DEFECT FREE ☐

1/4	INSPECTION IMPAIRED BY VEG. OR OTHER MAT'L (LF)	LINE TOT.(LF)	Q.L. (LF)	SUM OF QL(LF):
1				
2				TOTAL= SUM QL/4 (TF):
3				
4				%:

COMMENTS: CULVERT AT 2+50 IS BROKEN AND TRACK HAS SETTLED BADLY

FLANGEWAY MEASUREMENTS

COMPONENT CODE	LOCATION (e.g. sta or road, etc.)	MIN DEPTH (in)	MIN WIDTH (in)	FOULED	COMMENTS
[✓ GC] RR	INFANTRY ROAD	1.5	1.6	N [✓ Y]	
[✓ GC] RR	PARKING LOT 5	0.5	2.0	N [✓ Y]	
GC [✓ RR]	SEGMENT 107	2.0	1.9	[✓ N] Y	
[✓ GC] RR	STA 1+60	1.4	1.9	[✓ N] Y	

COMPONENT CODES

BS = BALLAST / SUBGRADE
BA = BRIDGE APPROACH
CB = CAR BUMPER
CS = CAR STOP
CU = CULVERT
DL = DERAIL
DR = DRAIN
EM = EMBANKMENT
GR = GAGE ROD(s)
GC = GRADE CROSSING
RA = RAIL ANCHOR(s)
RR = RAIL CROSSING
SS = SIGNS / SIGNALS
SP = SPIKE(s)
SW = STORM SEWER
TP = TIE PLATE(s)
OT = OTHER (specify in comments)

DEFECT CODES

BRK = BROKEN
CRB = CRACKED / BENT
BAD = BALLAST - DIRTY
ERO = EROSION
IMP = IMPROPER POSITION
IST = IMPROPER SIZE / TYPE
ISA = INSUFFICIENT AMOUNT
LOS = LOOSE
MIS = MISSING
NFL = NON - FUNCTIONAL
OBF = OBSTRUCTED FLOW
PMP = PUMPING
SET = SETTLEMENT
SLS = SLOPE STABILITY
STD = STRUCTURAL DETERIORATION
SUD = SURFACE DETERIORATION
TCA = TORCH CUT / ALTERED
WAS = WASHOUT

FIGURE 6 Completed other track components inspection form.

Ties are considered inspection impaired if less than half of the top surface is visible. The other two component areas use the concept of quarters for inspection impairment. For example, if the base on one side of only one rail is covered, then rail and joint inspection is one-quarter impaired. At the other extreme, four-quarters inspection impairment occurs when the base on both sides of both rails is covered. Quarters of inspection impairment are also used with "other track components"; the only difference is that the inspection impairment criterion is whether or not the spike heads are visible (instead of the rail base).

For each of the three component areas, obscuring foreign material is accounted for in terms of (equivalent) linear track feet and percentage of track length. These are calculated within the RAILER computer software based on data collected in the field during track inspection and can also be calculated manually if RAILER is not computer implemented. The field entries associated with inspection-impaired track are illustrated in Figures 2 and 6. An explanation of various categories shown in Figure 6 is given as follows:

- The ballast (component code: BS) is dirty (defect code: BAD) starting at Station 0 + 00 and continuing for 100 ft. This is not an immediate hazard.
- A culvert (CU) is clogged so that flow is obstructed (OBF). The culvert is a discrete item located at Station 0 + 50. This is not an immediate hazard.
- Three gage rods (GR) are loose (LOS). The first loose gage rod is located at Station 0 + 90. This is not an immediate hazard.
- Some spikes (SP) are improperly positioned (IMP) because of an improper spike pattern. Starting at Station 1 + 40 and continuing for 200 ft, about 50 percent of the spikes are improperly positioned. This is not an immediate hazard.
- A spike (SP) is missing (MIS) at Station 1 + 50. This is not an immediate hazard.
- An embankment (EM) is experiencing erosion (ERO) starting at Station 2 + 10 and continuing for 20 ft. This is not an immediate hazard.
- A culvert (CU) has suffered structural deterioration (STD). The culvert is located at Station 2 + 50. This defect is marked as an immediate hazard, and the comment indicates that the track has "settled badly," which could lead to unsafe car movement (e.g., rocking) if the track is used.

Flangeway Measurements

- A grade crossing (component code: GC) that crosses Infantry Road has an effective minimum flangeway depth and width of 1.5 in. and 1.6 in., respectively. The flangeways are fouled.
- A grade crossing (GC) that crosses Parking Lot 5 has an effective minimum flangeway depth and width of 0.5 in. and 2.0 in., respectively. The flangeways are fouled.
- A rail crossing (RR) that crosses Segment 107 has an effective minimum flangeway depth and width of 2.0 in. and 1.9 in., respectively. The flangeways are not fouled.
- A grade crossing (GC) located at Track Station 4 + 60 has an effective minimum flangeway depth and width of 1.4 in. and 1.9 in., respectively. The flangeways are not fouled.

In addition to undesirable foreign material, grade crossings (paved areas) also obscure track inspection. Grade crossing length is a RAILER inventory data element. This data element is used within the RAILER software to account for the effect of grade crossings on track inspection. For this reason, the inspection impairment associated with grade crossings can be ignored during track inspection field procedures if RAILER is computer implemented. Otherwise, the effect of grade crossings is accounted for in the field in conjunction with undesirable foreign material.

This process quantifies, for each of the three component areas, the amount of track that cannot be properly inspected. Procedures for using this information to estimate the hidden defects are still under development.

Relationship to Track Standards

Track maintenance or safety standards describe desired or acceptable track conditions. In addition, track standards may indicate the relative severity of various deviations from these acceptable track conditions (as the Army standards do).

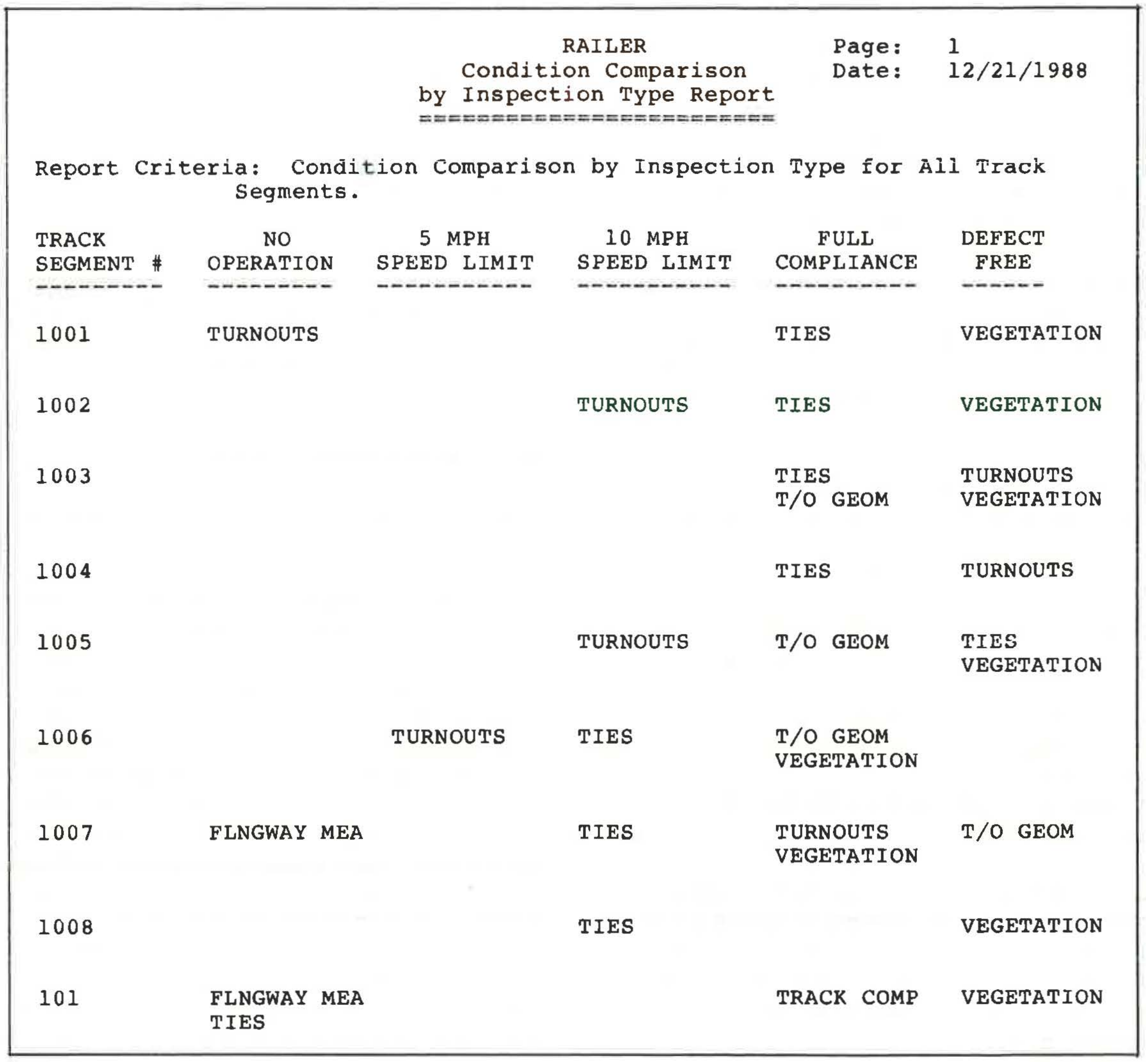
The first immediate goal of the detailed inspection procedures described here is implementing the Army Track Standards in a manner consistent with the RAILER program. However, RAILER is also designed to accommodate other track standards. For example, a version of RAILER is being developed for the U.S. Army in Europe that will incorporate German Track Standards. Also, it is envisioned that RAILER will be eventually transferred to the civilian/private sector for use by short lines, industrial networks, and possibly some branch line operations. These operators may wish to incorporate FRA or their own track standards.

In order to accommodate this flexibility, the inspection procedures are designed (as much as possible) to collect raw data, which are later compared within the computer with the appropriate standards (or possibly multiple standards). For example, instances of three consecutive defective ties are noted as raw data during tie inspection (see Figure 2). This defect implies a 10-mph operating restriction in the Army Track Standards. However, in some industrial situations, such as in a steel mill operation where eight-axle ladle cars regularly carry molten iron, management could elect to impose a more restrictive 5-mph limit, or perhaps prohibit all train movements, whenever three consecutive defective ties are encountered.

The analysis of the inspection data relative to a given set of track standards is provided in three RAILER "Comparison Reports" that vary in their level of detail. These are a Condition Summary, a Condition Comparison by Inspection Type (component area), and a Detailed Comparison. An example of the Condition Comparison by Inspection Type report is presented in Figure 7. The comparison results can be tied to a locally developed maintenance policy so that a Maintenance and Repair (M&R) report can be generated for work planning. This report can be generated in two levels of detail, an M&R Summary and a Detailed M&R. An example of the summary level is presented in Figure 8.

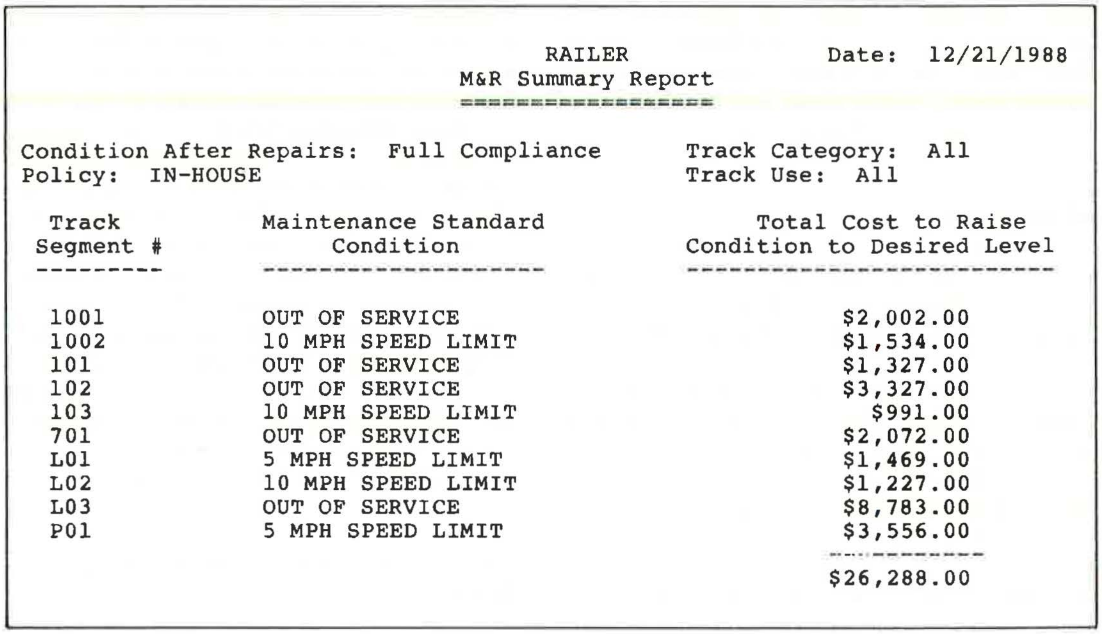
Use of a Computer to Simplify Inspection Procedures

Inspecting for all the defects specified in the Army Track Standards is a significant task. Therefore, an important con-



```
                                   RAILER            Page:    1
                            Condition Comparison     Date:    12/21/1988
                          by Inspection Type Report
                          =========================

Report Criteria:  Condition Comparison by Inspection Type for All Track
              Segments.

TRACK           NO          5 MPH         10 MPH         FULL        DEFECT
SEGMENT #   OPERATION   SPEED LIMIT   SPEED LIMIT   COMPLIANCE     FREE
---------   ---------   -----------   -----------   ----------    ------

1001        TURNOUTS                                TIES          VEGETATION


1002                                  TURNOUTS      TIES          VEGETATION


1003                                                TIES          TURNOUTS
                                                    T/O GEOM      VEGETATION


1004                                                TIES          TURNOUTS


1005                                  TURNOUTS      T/O GEOM      TIES
                                                                  VEGETATION


1006                     TURNOUTS     TIES          T/O GEOM
                                                    VEGETATION


1007        FLNGWAY MEA               TIES          TURNOUTS      T/O GEOM
                                                    VEGETATION


1008                                  TIES                        VEGETATION


101         FLNGWAY MEA                             TRACK COMP    VEGETATION
            TIES
```

FIGURE 7 Condition Comparison by Inspection Type report.



```
                                   RAILER             Date:  12/21/1988
                              M&R Summary Report
                              ==================

Condition After Repairs:  Full Compliance       Track Category:  All
Policy:  IN-HOUSE                               Track Use:  All

  Track            Maintenance Standard            Total Cost to Raise
 Segment #              Condition               Condition to Desired Level
 ---------         ---------------------        --------------------------

  1001             OUT OF SERVICE                          $2,002.00
  1002             10 MPH SPEED LIMIT                      $1,534.00
  101              OUT OF SERVICE                          $1,327.00
  102              OUT OF SERVICE                          $3,327.00
  103              10 MPH SPEED LIMIT                        $991.00
  701              OUT OF SERVICE                          $2,072.00
  L01              5 MPH SPEED LIMIT                       $1,469.00
  L02              10 MPH SPEED LIMIT                      $1,227.00
  L03              OUT OF SERVICE                          $8,783.00
  P01              5 MPH SPEED LIMIT                       $3,556.00
                                                         ------------
                                                          $26,288.00
```

FIGURE 8 Maintenance and Repair Summary report.

sideration in developing these inspection procedures was easing, as much as possible, the burden of the inspector. This was accomplished in several ways, including, as discussed previously, in the design of the inspection forms.

The RAILER computer software provides another means to this end. The focus on collecting raw data (as discussed previously) is an important example. This is especially true of measurements such as those obtained during turnout inspection (see lower portion of form presented in Figure 3). The inspector does not need to know the acceptable value ranges and the cut-off points for different operating restrictions (severity levels). The inspector only needs to properly make the measurement(s) and enter the values on the form. These values are later compared with the standards, either in the computer or by hand if RAILER is not computer implemented.

The computer software is also designed to prevent the entry of some obviously inconsistent defect combinations such as rail anchors that are pumping (see in Figure 6 Component Code RA and Defect Code PMP). This increases the reliability of the inspection process.

SHORT-LINE APPLICABILITY

Potential technical transfer to the civilian sector is an important consideration in research conducted by the federal government. Early in the development of RAILER, it was observed that many characteristics associated with Army track maintenance management are also true for commercial short lines and industrial networks. These common characteristics include general track quality, service levels and types of operations, and the availability of local expertise.

Therefore, potential use by short lines was a strong consideration throughout the development of RAILER. This was partially accomplished by introducing into RAILER the necessary flexibility to accommodate those areas in which the Army's needs are not completely consistent with those of potential civilian users. An example of this flexibility is the ability to develop within RAILER customized track standards as discussed previously. The RAILER detailed inspection procedures provide the same benefits for short-line users, as they do for Army users.

FIELD TESTING

The detailed inspection procedures described here have been under development for over 3 years. They have evolved into their present form with the concurrent development of the Army Track Standards. Both involved considerable revision during their history. The development was an iteration process; needed information was ascertained, procedures were then developed to collect the information, these procedures were field tested, and revisions were made. The overall goal was to be able to easily collect the necessary information with trained installation track inspectors.

Many weeks were spent in the field testing the procedures. Teams were sent to the Tooele Army Depot, Utah; Ft Devens, Massachusetts; Ft Stewart, Georgia; and Hunter Army Airfield, Georgia. Additionally, the Urbana, Illinois, yard of the Consolidated Rail Corporation (Conrail) served as a local site. Generally, data collection procedures were first developed in the laboratory and tested locally. Then, field trips to the installations were scheduled to uncover procedural shortcomings. The various locations were chosen to provide the great variety of operating, climatic, and maintenance differences that were needed to properly test and evaluate the data collection procedures. Also, the field work permitted the researchers to test the practical requirements of the Army Track Standards. Feedback to the developers of the standards resulted in some changes. Those, in turn, resulted in inspection changes and data collection modifications.

The field work has shown that inspection productivity rates are strongly dependent on the condition of the track (i.e., the more defects there are, the longer the inspection takes). The inspections may only progress at a slow walking pace. This is because many of the defects are quite finite and require acute attention to be observed. Also, for the same reason, it was found that it can be nearly impossible for a single inspector to inspect all of the components concurrently. In fact, it may take up to three passes of the track by one inspector to note all of the defects for all of the components. The track can be inspected by one person, but a team of two significantly improves the efficiency; it can be nearly impossible for one person to perform certain manual track geometry inspection tasks.

Based on the range of conditions found at the various installations, one inspector could completely inspect, on foot, approximately 0.3 mi/hr. Turnouts take approximately 15 min each to inspect (time actually spent at the turnout). These are average rates and include allowance for nonproductive walking time (time lost walking back from the end of a terminating track at the completion of an inspection). They do not include travel time to and from the network portion being inspected.

A two-person inspection team was found to be able to inspect at a rate of approximately 0.8 mi/hr. Turnout inspection can be reduced to approximately 8 min.

None of the above productivity rates includes time for manual track geometry measurements.

Track inspection from a moving track vehicle, even at slow speeds (<5 mph), resulted in a number of missed defects.

CONCLUSIONS AND RECOMMENDATIONS

The detailed inspection procedures described in this report were developed for use within the RAILER system. The inspection data collection forms were developed to facilitate relative ease in data collection and recording, as well as eventual loading into installation RAILER data bases for processing and analysis. Testing has shown that this has been accomplished.

These same detailed inspection procedures were designed to satisfy the requirements of the Army Track Standards. The methods and procedures described in this report can be used to satisfy the inspection requirements of those track standards.

Also, these inspections are currently intended to satisfy several maintenance management requirements at both the network and project levels (*1, 2*). At the network level, these include identifying safety problems, assessing conditions, developing long-range work plans, budgeting, and prioritizing work for the entire network. Project-level management focuses on specific track segments and includes quantifying work needs associated with preparing job orders and contracts, determining the cause of the track problems, and selecting the most feasible M&R alternative.

The detailed track inspection procedures are explicitly designed to provide the information required for project-level management, in which detail becomes very important. However, much of that detailed information is not needed for network-level management tasks. Network-level management tasks are performed at least annually, whereas project-level tasks are performed only when and where needed. Thus, most management tasks are at the network level.

The authors believe that management needs should dictate data requirements, not vice versa. Specific information should be collected only when needed to satisfy management needs. Accordingly, simplified track inspection procedures are being formulated as part of the Track Structure Condition Index (TSCI) development currently under way at USA-CERL. The TSCI will measure the "health" of both individual track segments and the overall network. This measure will be the prime tool for network-level management tasks. The new simplified inspection procedures will capture just enough information to perform those tasks, yet at the same time be sensitive enough to identify critical defects requiring immediate attention for safety reasons. The spirit and intent of the Army Track Standards will still be met. A tangible benefit consisting of a significant reduction in inspector hours would result. The detailed inspection procedures described in this report would be reserved for project-level management tasks.

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