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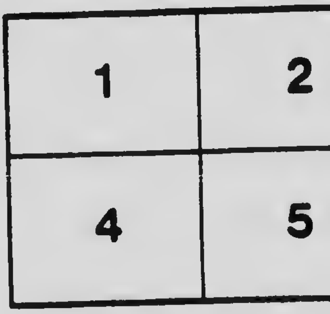
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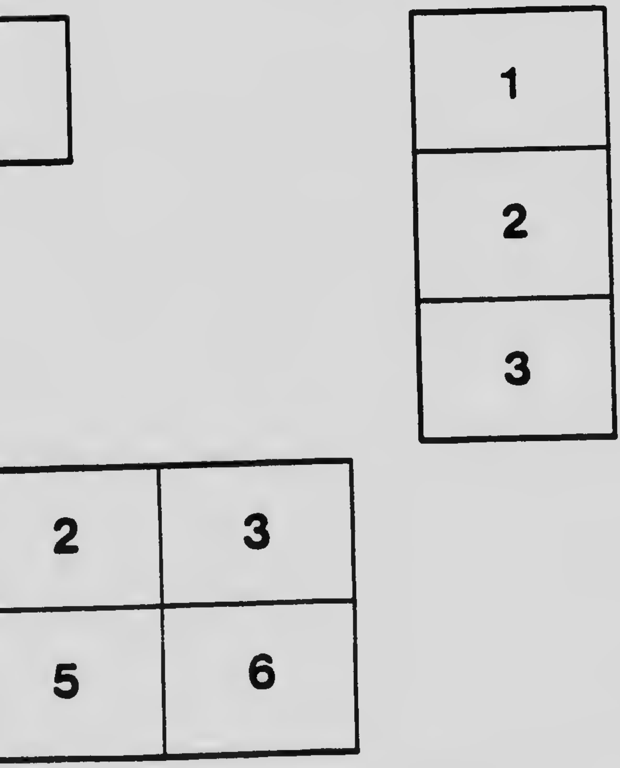

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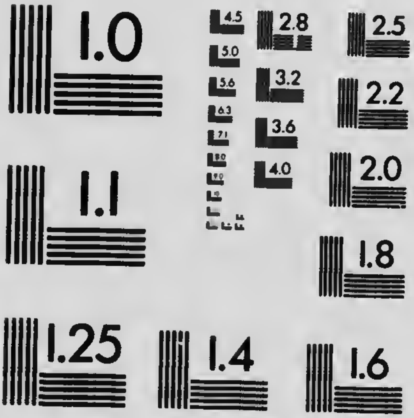

Railway Reconnaissance

BY

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1903

REPRINTED FROM "THE CANADIAN ENGINEER"

RAILWAY RECONNAISSANCE.*

BY WM. B. MACKENZIE, CHIEF ENGINEER, INTERCOLONIAL RAILWAY.

Railway work generally begins with an examination of the country through which it is desired that the line shall pass. This is called a "reconnaissance," and may be considered an art rather than a science. The best procurable map of the country, an axe, a pair of steel climbers, a pocket barometer, field glass, and a 7-inch Abney double-tube hand level, having vertical arc, compass and telescope combined, are the only instruments really needed. Good work may be done without any of them, but they are a convenience. The catalogue prices of several very useful pocket instruments for reconnaissance are: Pocket barometer, $27; field glass, $35; Abney's double-tube 7-inch hand level with vertical arc compass and telescope combined, $17; Brunton pocket transit, $25; pocket magnifying glass, 55c. A guide should be employed, and the man who thinks he knows the whole country and every tree in it is, no doubt, the best man to have; but you must be careful to prove the correctness of his knowledge by your own work, and take nothing for granted. If he is a farmer he will lead you along the highways, and if a hunter, he will lead you along the ridges. I once came near making a very serious error in location by depending too such on a guide who "knew it all." After the completion of the survey, I had a feeling that to make assurance doubly sure, I should take two or three days to go crosswise over the country, and thus confirm the route selected beyond question or the possibility of a doubt. By the evening of the first day I had proved that in one place the line was a mile out of the proper position; three miles of new survey was made and the line built on it. That was a bit of experience which I shall not soon forget. I felt very thankful but the guide was correspondingly cast down.

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*Extracts from a Paper entitled "Notes on Railway Work," read before the Engineering Students of the University of New Brunswick at Fredericton, N.B. October 17th, 1902.

It will be necessary for the engineer to explore the country for several miles on each side of a direct line on the map connecting the terminal points, because, no matter whether he is on the right track or not, every farmer he meets will tell him that the line should be somewhere else two or three miles away, and he must be able to tell them that he has been there already, and knows more about the ground than they do. The general route can be selected by reconnaissance and without the use of a transit or level, and the man who possesses the greatest skill in estimating distances, heights and grades by the eye alone, will do the best work and will do it the most rapidly. This is where the "born locator" having an "eye for country" will shine.

Reconnaissance work requires a higher order of mind than is called for in merely running in or locating the line on the ground in detail by the use of the transit and level, or in constructing it afterwards. The whole question of operating economy depends upon the reconnaissance, and no excellence of construction can correct mistakes in it. Only men of proven ability in reconnaissance should be allowed to undertake this most difficult part of railway work—the part which irrevocably fixes the character of the road. All the railways of the country are now suffering more or less from insufficient reconnaissance work having been done before their final location, and this very serious error should not be repeated in future railway work in Canada. Not a location stake should be set until the reconnaissance is completed, and in difficult country a day to one or two miles will be time well spent.

In future, the reconnaissance man will be the important man, and it will be necessary to seek him with a lighted candle and pay him well when found. He will be a man of tact and judgment—one in a hundred—a man who loves the woods, knows some of its secrets and feels as much at home in the forest as in his own house, if he happens to have one. No matter how difficult the country may appear, always assume that there exists a good line between the two terminal points and that it is your business to find it. Do not allow the mind to become prepossessed in favor of a particular line until you have exhausted all the possibilities. Do not adopt too high a maximum gradient, because it is the ruling grade which governs the cost of operation, and low grades are the most important of all the details. When a valley rules the location laterally, the problem is simple, but when the line runs across the drainage of the country, it is complex. A preliminary reconnaissance should first be made by driving over the country from one terminal point to the other, in a carriage or on horse-back, or on foot when there are no roads, to ascertain the general features, returning again to the starting point Next, the controlling points should be noted on the map, and examined by walking over them in both directions, and it must be ascertained and decided in a general way whether they can be overcome within the limits of grade and curvature. Of course, the lowest point on ridges will be selected and the highest stream crossings where the grade must be continuous between the stream and the summit. Where a stream flows east or west the smoothest ground is generally found on the north side, and when the stream flows north or south, the smoothest ground is generally found on the west side. The grade of all streams increases toward the source. It is absolutely necessary to know where the water of every stream goes to. In examining the ground from tall trees or from hill-tops in rolling country, a person is liable to form entirely wrong impressions and imagine the ground to be much more easy than it really is. A rolling, irregular country, having pieces of hills and valleys scattered about promiscuously and trending in different directions, is the most aggravating kind of country to the locating engineer, and it requires a great deal of hard work before he can be assured that he has secured the best line; almost any person can locate along a shore or river valley. Except, perhaps, at summits, do not let the existence of a highway have any influence on your location. The pocket barometer is a very useful instrument, but, like the guide, it is very apt to lead you astray, and requires careful watching.

Things are not always what they seem, and you must be continually on your guard against what is termed "Ocular illusions." For instance: A slope observed in front with the sky as a background always appears higher and steeper than it really is. Looking against a mountain you will imagine the ground falling towards the mountain when it is really rising, and a stream flowing towards you will appear to be running up hill. If, at the foot of a mountain, there is a small hill with a valley the same height on each side of it, the valley next the mountain will appear to be the lowest. Hills overlapping at a distance will give the appearance of a solid ridge, many errors have been made from this cause. Fills are deeper than they seem to the eye looking directly down on them. When a slope is observed from the top, it appears to be steeper than it really is. Longitudinal distances appear shorter than they really are when looked at across water or low land. Lateral distances are exaggerated and appear longer than they really are. In clear air, judging distances is almost impossible without comparison with some known distance, but practice will show at what distance known objects, such as the outline and style of a man's hat, becomes visible. The distance to a rock observed across an unseen valley is almost impossible to estimate. In a hazy atmosphere, the amount of haze between you and the object is some guide to the distance. When looking towards the setting sun, the distances are less than they appear to be. Heights and distances are more easily judged on days when the sun is obscured. Distances can often be taken with sufficient accuracy by observing the time occupied by the passage of the report of a gun from one point to the other. This may be done in the day time if there is a field-glass handy to watch for the smoke, but otherwise the flash, of course, can be best seen at night. The velocity V, in feet per second, with which the sound travels depends on the temperature; thus, at 32 degrees F., V equals 1,090 feet; at 60 degrees F., V equals 1,125 feet, and at 100 degrees F., V equals 1,175 feet. If the wind is blowing hard in the direction from which the sound comes, the velocity of the wind may be added to V. When the observers are not visible to each other, two guns may be used. If one fires instantly on hearing the other, repeating this three or four times, one-half the number of seconds from the firing of your gun to the reply of the other, multiplied by V, will give the approximate distance in feet. Sounds travel to greater distances in cold air; they are not easily heard during snowstorms, but they ascend readily and are more distinctly heard on the hill-tops.

If your pocket compass has been forgotten, and the sun being invisible, you discover that you are lost, a few of the secrets of the woods may be of service. You will find a compass almost anywhere by observing that moss and fungus grow on the north side of the trees, that a lonely bare rock will show the south side, dry and bare, and the north side damp, mouldy and mossy. The sunny or south side of a hill will be dry and noisy under foot, while the north side is mossy and damp; this also applies to clumps of trees, bushes, big rocks, etc. The golden-rod droops to the south, and the color of the club rush (cat-tail), is lighter on the south side. The bark of the coniferous trees is of a lighter color, harder and dryer on the south side, and is darker, damper and sometimes carries moss on the north side. The gum or balsam is clearer, cleaner and harder on the south side, and soft sticky and full of insects and dirt, and gray on the north side. Nests and webs of insects are in the crevices of the bark on the south side. Birds' nests are usually built and woodpeckers' holes usually on the south side the trees. The green leaves are of a lighter color on the south side. On steep hills or mountains, trees grow larger and more uniform on the north slope, next best on the east slope, while on the south and west slopes, the ground is often bare. It is well to note the direction of the wind each morning and the dip of the rocks, if uniform, as this knowledge alone may help you out of the difficulty. If the direction of the prevailing wind in that part of the country is known, an isolated and exposed tree will show it, as it will be found to lean more or less away from the prevailing wind. If it is known that a noted gale from a particular quarter once blew down large sections of the forest, look at the fallen trees. If you wish to know the age of a blaze on a tree, cut squarely through the wood which has grown over or partly over the blaze and count the annual rings from the black mark outwards. In the eastern part of Canada quartz veins run nearly east and west, and ice markings on the rocks run southeast.

After you have succeeded in finding yourself again, some of the important considerations may occupy your mind, such as the following: The difference in gross receipts between different lines. The difference in interest charges between different lines. The difference in operating expenses between different lines. Deviations to outlying villages which may be made to secure local traffic, and these may extend to 1-10 the air line distance between terminals measured on either side from the air line itself. Ten per cent. of the traffic originating in small towns will be lost for every mile the line is placed away from the town. Such towns, however, gradually build up towards the railway; 25 per cent. to 50 per cent. of the traffic originating in cities where there is competition will be lost for every mile the line is placed away from the city. Stations should be as nearly as possible in the centre of the cities or towns, particularly at terminals. For lines of heavy traffic (say ten trains per day, round trip): If the gross revenue can be increased 1-5 the whole investment may be doubled. If the gross revenue can be increased 1-10 the cost of track and roadbed may be doubled. If the gross revenue can be increased 1-20 the cost to subgrade may be doubled.

Distance.—For savings of three miles or less, assume that the cost of operation is 80 cents per mile for every daily train making a round trip (going and returning). Then 80 cents x 350 days in the year = $280 per year per daily train round trip (going and returning). If borrowed money costs 5 per cent. interest, we are entitled to spend $5,600 extra on construction of a certain route, if by so doing we can save a mile of level track, because this is the sum which at 5 per cent. interest will produce $280. For two trains making round trips per day (going and returning), we should spend twice as much, and so on.

Rise and Fall.—Assume an operating cost of 80 cents per mile for every daily train making a round trip (going and returning), then on grades between 0.75 and 2.00 per 100, when hills are 40 to 50 feet high, the annual cost for operating one foot of rise and fall per daily train round trip (going and returning) may be estimated at $1.44. If borrowed money costs 5 per cent. interest, we are entitled to spend $28.80 in the reduction of one foot of rise and fall, because this is the sum which at 5 per cent. interest will produce $1.44. For two trains making round trips per day (going and coming), we should spend twice as much, and so on.

For such a summit as "C" in Fig. 1, spend 2 x $28.80 = $57.60; but if "C" is the terminus of the line "AC," spend only s28.80.

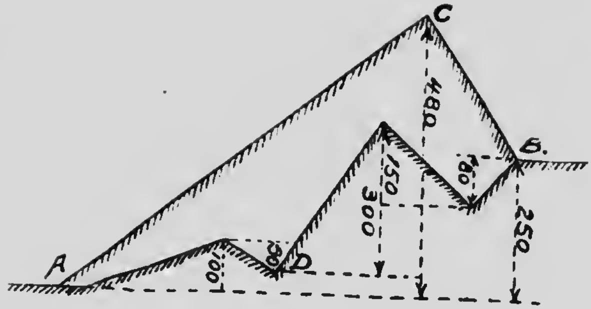

Fig. 1.

A foot of rise and fall means one foot of rise and one foot of fall, going in one direction only. Thus in Fig. 1, the total rise and fall between "A" and "B" by either route equals 710 feet.

Curvature.—Assuming an operating cost of 80 cents per mile for every daily train making a round trip (going and returning), the annual cost of operating one angular degree of curvature per daily train round trip (going and returning), may be estimated at 28½ cents. If borrowed money costs 5 per cent. interest, we are entitled to spend $5.70 to lessen a curve by one angular degree of curvature, because this is the sum which at 5 per cent. interest will produce 28½ cents. For two trains making round trips per day (going and returning), we should spend twice as much, and so on.

Locomotive Haulage.—To find the load which a locomotive can haul up a given grade at ordinary freight speed, use the following formula:

$$L = \frac{100W}{1 + 4r} - E \qquad (1)$$

L = Load in tons of 2,000 lbs., which can be hauled behind tender.

W = Weight on the drivers in tons of 2,000 lbs.

E = Weight of locomotive and tender in tons of 2,000 lbs.

r = per cent of grade.

The above is based on a rolling resistance of 5 lbs. per ton on straight level track.

Note—Deduct 20 per cent. from L in winter.

Comparison of Routes.—A line is 50 miles long between terminal points and has a ruling grade of 1¼ per 100. How much additional money would we be entitled to spend to secure a 1 per 100 grade, having to carry 2.000 tons of freight in one direction every week day? By applying formula (1), it is seen that our engine will haul 1,000 tons up a 1 per 100 grade, and only 824 tons up a 1¼ per 100 grade—a difference of 176 tons per train. On the 1 per 100, therefore, we would require two trains per day, carrying 1,000 tons each, while if we used the 1¼ per 100 grade, we would have 176 tons × 2 trains × 6 days = 2,112 tons of freight piled up at the receiving end at the close of each week. This would require two special trains per week = 0.33 of a daily train, and to operate these two special trains would cost annually: 0.33 of a daily train × 80 cents per mile per daily train round trip × 50 miles × 350 working days in the year = $4,620, and this capitalized at 5 per cent = $92,400, which is the additional sum that we would be entitled to spend to secure a 1 per 100 grade instead of a 1¼ per 100 grade.

Now, we may accomplish this in either of two ways; either spend the $92,400 in cutting down the 1¼ per 100 grade to a 1 per 100 grade, or, if this cannot be done, divert the line on to new ground which will afford a 1 per 100 grade and add 3½ miles to its length. This latter proposition is proven thus:

To operate one train round trip over one mile additional during one year........	= $280 = 80c. × 350 days
	2 trains
To operate two trains round trips over one mile additional during one year........	560
	3½ miles
To operate two trains round trips over 3½ miles additional during one year.......	1,960
Assuming construction to cost $52.500 for 3½ additional miles 5%	2,625
Annual outlay, which nearly equals the $4,620 that we are entitled to spend annually to secure a 1 per 100 grade.................	$4.585

Business and ruling grade should determine the general route. Most of the lines of 20 and 30 years ago were pioneer lines, and steep grades and sharp curves were freely used to lighten the cost of construction, as nothing else would have been paid for at that time. There was not then the same necessity for the extensive and thorough reconnaissance which is now imperative in this day of heavy traffic and low grades.

Far too little time was formerly given the engineer for reconnaissance work. In my own experience I once, because of an incorrect plan, ran my preliminary line into a lake, instead of passing by the end as I intended. As the work had already been advertised for tender, no time was left to make changes, and the road to-day runs through the middle of the lake. Once, after completing the reconnaissance, I put on two survey parties, and, while keeping ahead of the preliminary party and giving them general directions, I was able, with the aid of 20-in. x 30-in. sheets on which the preliminary work had been plotted the night before, to lay down the location at odd times in the day, using the flat wooden case in which the sheets were carried as a table. These sheets were, one by one, carried back to the locating party, and the whole combination was thus kept moving. Such work is too much for one man, and those who do it receive few thanks as a rule.

Be sure that you do not use the maximum grade or curve oftener than is absolutely necessary. When you are climbing toward a summit, try to avoid losing elevation by inserting reverse or down grades, but look well for supporting ground to right or left, and thus by gaining distance reduce the rate of grade. If the country is such that high grades must somewhere be used, try to bunch them in one division, and reduce grades to the utmost on all the other divisions.

Reconnaissance should be so thorough that a close preliminary line can be run and sufficient topography taken within 300 or 400 feet on either side. This may be shown on plan by contour lines or elevations in figures. From this data, a paper location plan and profile is made. When running in this paper location is the time to study the ground in detail and make necessary changes. This general method of reconnaissance and preliminary, having the details filled in to the extent necessitated by the character of the country, should result in good location at reasonable cost.

For practical information on railway location and construction, consult "The Economic Theory of Railway Location," by Wellington, 1887; a series of articles by Wm. G. Raymond, in the Railroad Gazette, November and December, 1898, and "Rules for Railway Location and Construction," by E. H. McHenry, chief engineer of the Northern Pacific Railway, now chief engineer of the Canadian Pacific Railway. The latter book is the most comprehensive and complete book of instructions so far published on the subject, and it has recently been reprinted by the Engineering News Publishing Co.. New York. Price, $1.