LAYOUT DESIGN assessment formulas

by Joe Fugate

Photos by the author

Find out if your layout will work before you build it

1. When Joe Fugate designed his HO Siskiyou Line, he used some track planning formulas adapted from a 1960's *Model Railroader* article by Dr. Roy F. Dohn. In this article, Joe presents the updated formulas he used, so you too can take these formulas and evaluate your track plans.

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You've just located two published track plans that both fit the space you have, and they're both for one of your favorite roads. But, you wonder, which plan will better meet your operating expectations? Even though you like the aesthetics of both designs, which will take less money and time to build?

Is there an easy way to find some quick, concrete answers to these questions before you cut the first stick of lumber? The answer is a resounding “Yes!” With a calculator, ruler, and a scale track plan, you can get solid answers to these questions with an hour or two of analysis.

LAYOUT DESCRIPTION STATS

Let’s look at these basic “layout description” statistics and how to compute them. We list each stat name (with its units), define it briefly, tell how it is calculated, and then discuss what that stat tells us about the design.

ROOM AREA (sq ft): Calculate the layout room’s square footage. If your room is much larger than the layout – such as a 4x8 layout in a large family room – then only include a reasonable amount of access space around the layout – don’t include all that extra room space. For instance, with a 4x8 layout in a large recreation room, you might add a 2 foot aisle all around the layout. This means the total “room area” for a 4 x 8 layout might be 8 x 12, or 96 square feet.

This stat tells us the approximate space requirement for a given layout, regardless of its shape. This is a clue that two differently shaped layouts could be altered to fit into each other’s space. This won’t always work, but at least it’s worth exploring.

LAYOUT AREA (sq ft): Calculate the total area taken up by just the layout “tabletop” itself. This does not include aisle space. For the 4x8 layout, this will be 32 square feet.

“By comparing the room area with the layout area, we can ascertain how well the layout design fills its space.”

This stat allows us to see just how much layout we really have, and is a valuable design statistic since it allows us to directly derive the amount of benchwork and scenery the layout needs.

By comparing the room area with the layout area, we can ascertain how well the layout design fills its space. For instance, the 4x8 layout’s space usage is 32/96, or 33%. Most along-the-wall designs have a space usage of 50% or more, which shows us the 4x8 layout doesn’t fill the space nearly as well as an along-the-wall design.

Filling the space isn’t the only issue, since we could build a wall-to-wall table and fill the space 100%. Access, however, would be abysmal. As long as good access is maintained, this stat is useful – but it must be viewed in context with your other design needs and goals.

NUMBER OF TURNOUTS: To compute this stat, just count the number of turnouts on the track plan. Also count a crossing as a turnout, and count a single slip switch or three-way turnout or single slip switch as two turnouts. Count a double slip switch as three turnouts.

This stat is a good indicator of trackwork complexity, which tells us many useful insights. Given that the most costly trackwork is a turnout, the most maintenance intensive trackwork is a turnout, and the most interesting trackwork operationally is a turnout – depending on what trade-offs we're after (less cost, less maintenance, more interesting operation), more or fewer turnouts may be preferable.

Combining this stat with the next one on total trackage gives us enough information to do a rough estimate of the trackwork and wiring costs for the layout.

Scale	Cars/ft
O	1
S	1.5
HO	2
N	4
Z	5

TOTAL TRACK (ft/cars): Determine how many feet of track are on the track plan by measuring it. Record the result as both total footage and as the equivalent number of 40 foot cars. Using 40-foot cars in the stats allows us to directly compare track plans across scales. To determine the 40 foot cars equivalent for a track plan, use the appropriate factor from the table on the left.

For instance, if an S scale layout has a total track of 211 feet, then the cars equivalent will be 316 cars (211 x 1.5). Drop any fractions – don't round. It's best to deal only with whole car lengths and lean to the conservative side when computing car capacities.

This stat, in combination with the other track stats below, tells us much about the operational possibilities of the track plan.

MAINLINE TRACK (cars): Measure the length of the mainline in feet and convert it to the cars equivalent. The main route of a branchline is also considered mainline for the purposes of computing this statistic. Also, one track running through any visible yard and any staging yard needs to be designated as part of the "main" and included in this total.

As an exception, the offstage portion of a single track that runs into staging to be used as car storage/interchange is not "mainline" but instead is "staging" (see below).

From this stat, we get a sense of how much "mainline" running is available on the layout.

PASSING TRACK (cars): Measure the length of each passing siding in feet and add them together. Do not count track where the main would be fouled if cars were on the siding. That short chunk of track from the turnout points to the clearance point is connecting track (see below), not passing track. Convert this figure to the cars equivalent.

This stat helps us determine mainline traffic levels (more on this later).

"Using 40-foot cars in the stats allows us to directly compare track plans across scales."

STORAGE TRACK (cars): Storage track is the amount of track in industrial spurs and yard storage (but don't include staging, that's a separate category below). Measure and total up the length of track in this category, and convert it to the cars equivalent. Like passing track, don't count track in this total where the connecting track would be fouled. Remember one track running through any yard was counted in the mainline total and is not to be included in this total.

STAGING TRACK (cars): Measure the total amount of track used to stage trains and compute the cars equivalent. Again, don't count track where the connecting track would be fouled. Don't forget that one track running through any staging area was counted in the mainline total and is not to be included in this total.

Remember the one exception – the offstage portion of a single-track car storage/interchange track is "staging," not "mainline."

SERVICE TRACK (cars): Service track is loco storage, servicing, turntable, turntable leads, and so on. The rule of thumb is: if the track is used to store cars, then it is storage (or staging if it is "offstage"), if it is used to store locos and is traversed primarily by only locos, then it is loco service track. Measure the total amount of track used to service locos and compute the cars equivalent.

CONNECTING TRACK (cars): Connecting track is what's left. Compute it as:

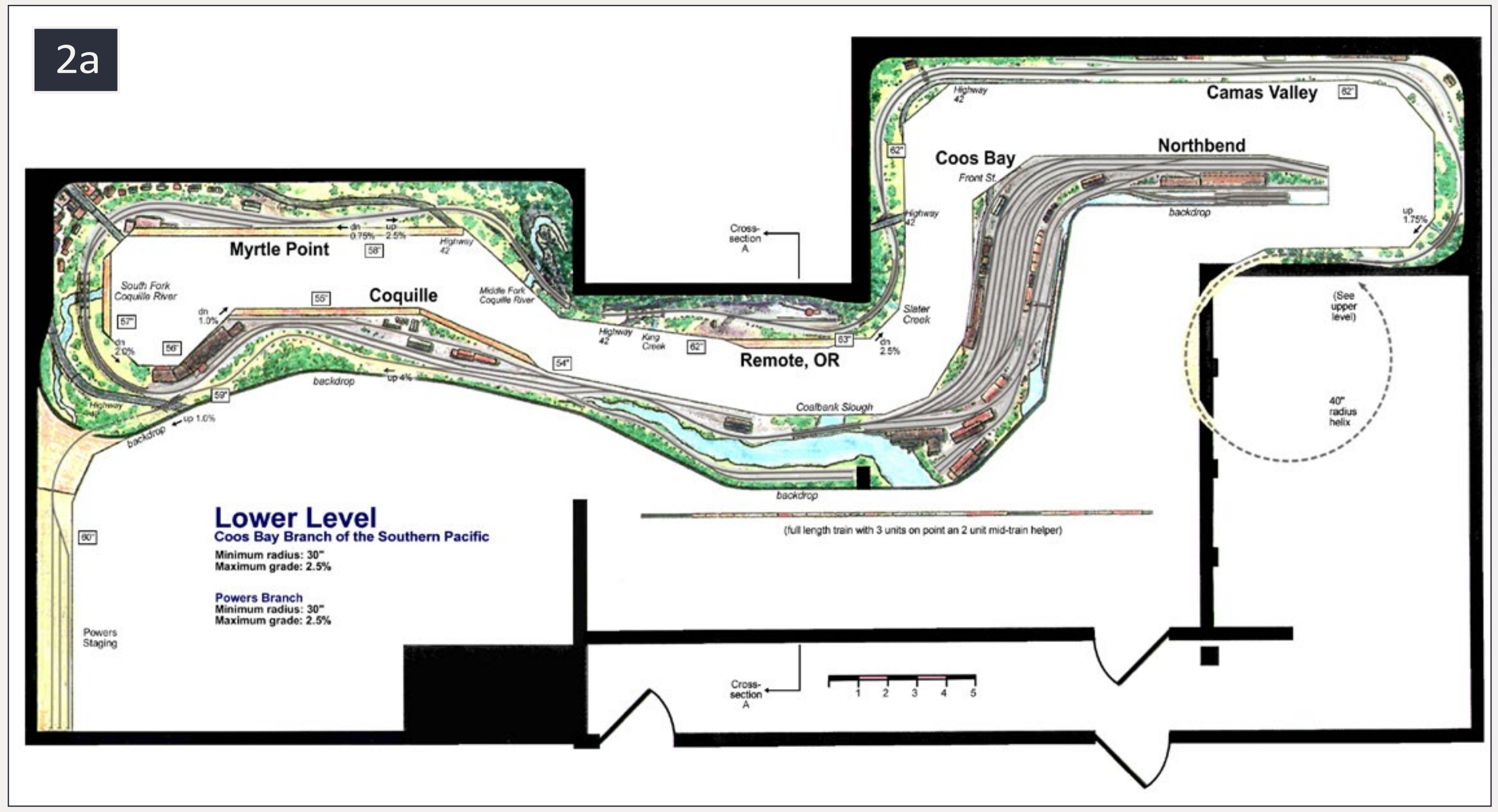
Connecting track = total track - mainline - passing - storage - staging - service

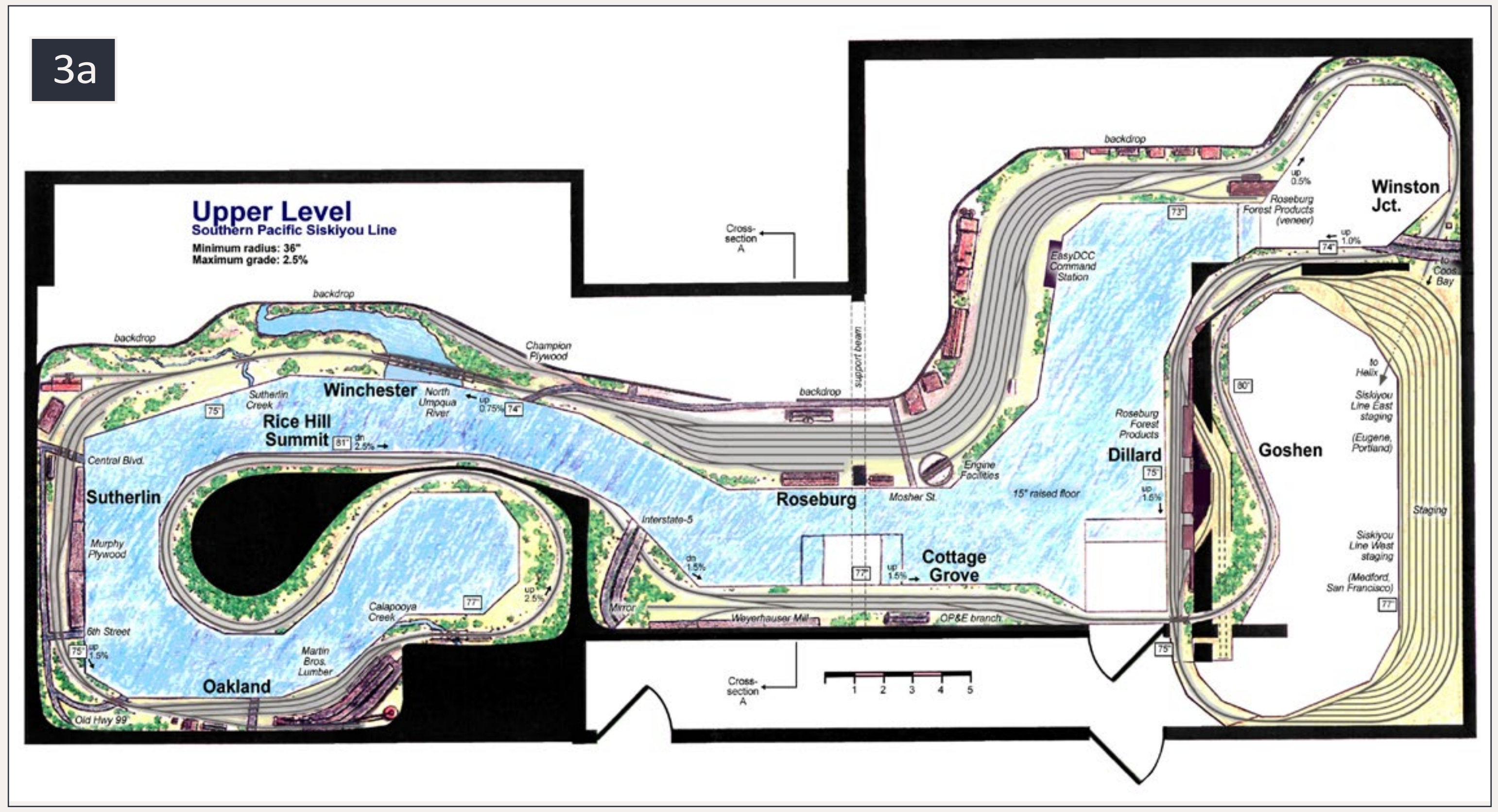
Connecting track is what allows us to make up and break down trains, and to maneuver cars from the main to industrial spurs and yard tracks. It turns out this track is essential to getting a layout that can move a lot of cars.

PASSING SIDINGS: Record the number of passing sidings.

PASSING TRAIN LENGTH (Cars): Write this stat as three values separated by slashes – longest/average/shortest. Longest is the length of your longest passing siding in cars. Average is the length of an average passing siding in cars, computed as: passing track / number of passing sidings. Shortest is the length of your shortest passing siding in cars.

STAGING TRACKS: Record the number of staging tracks.

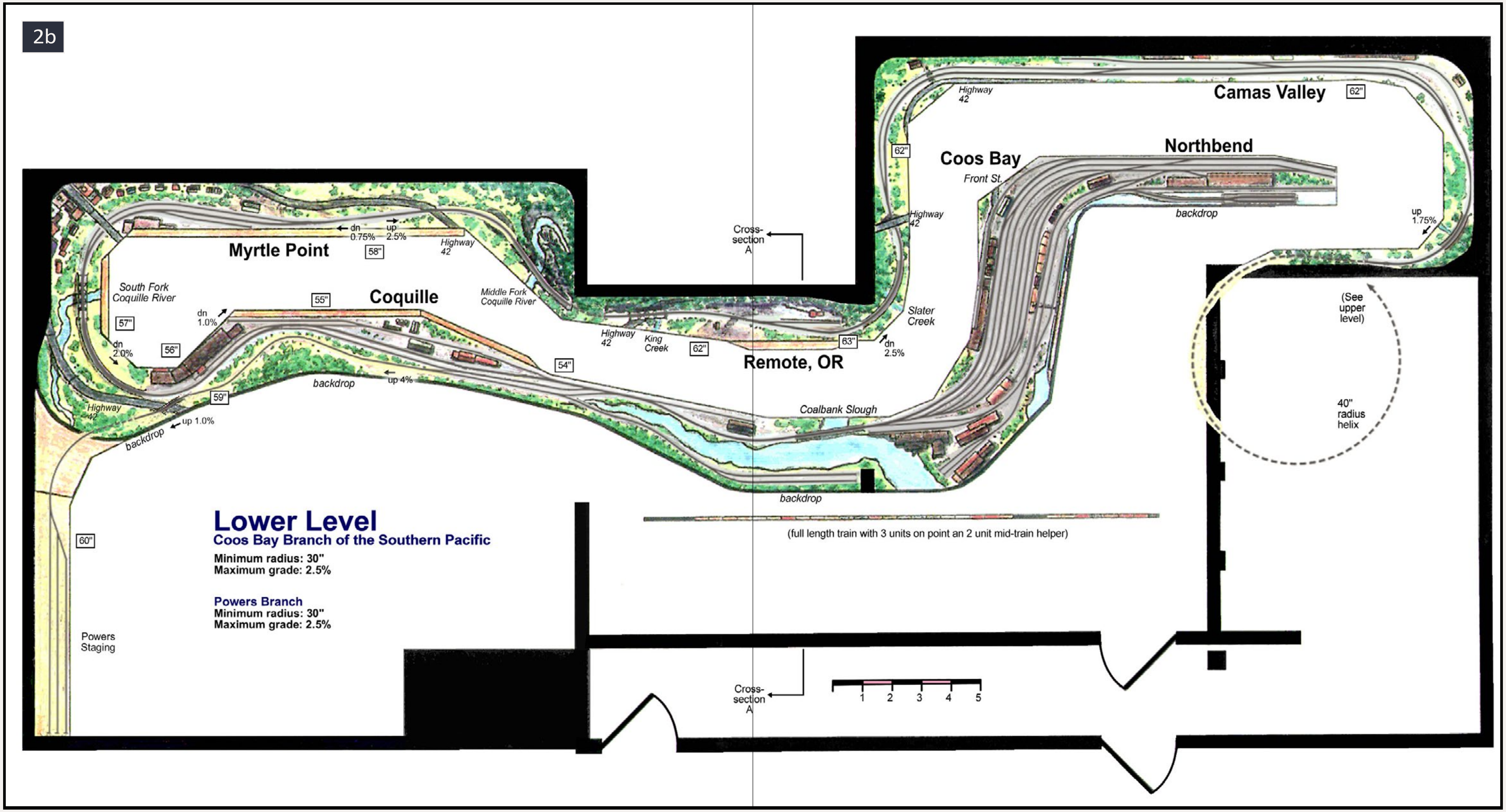




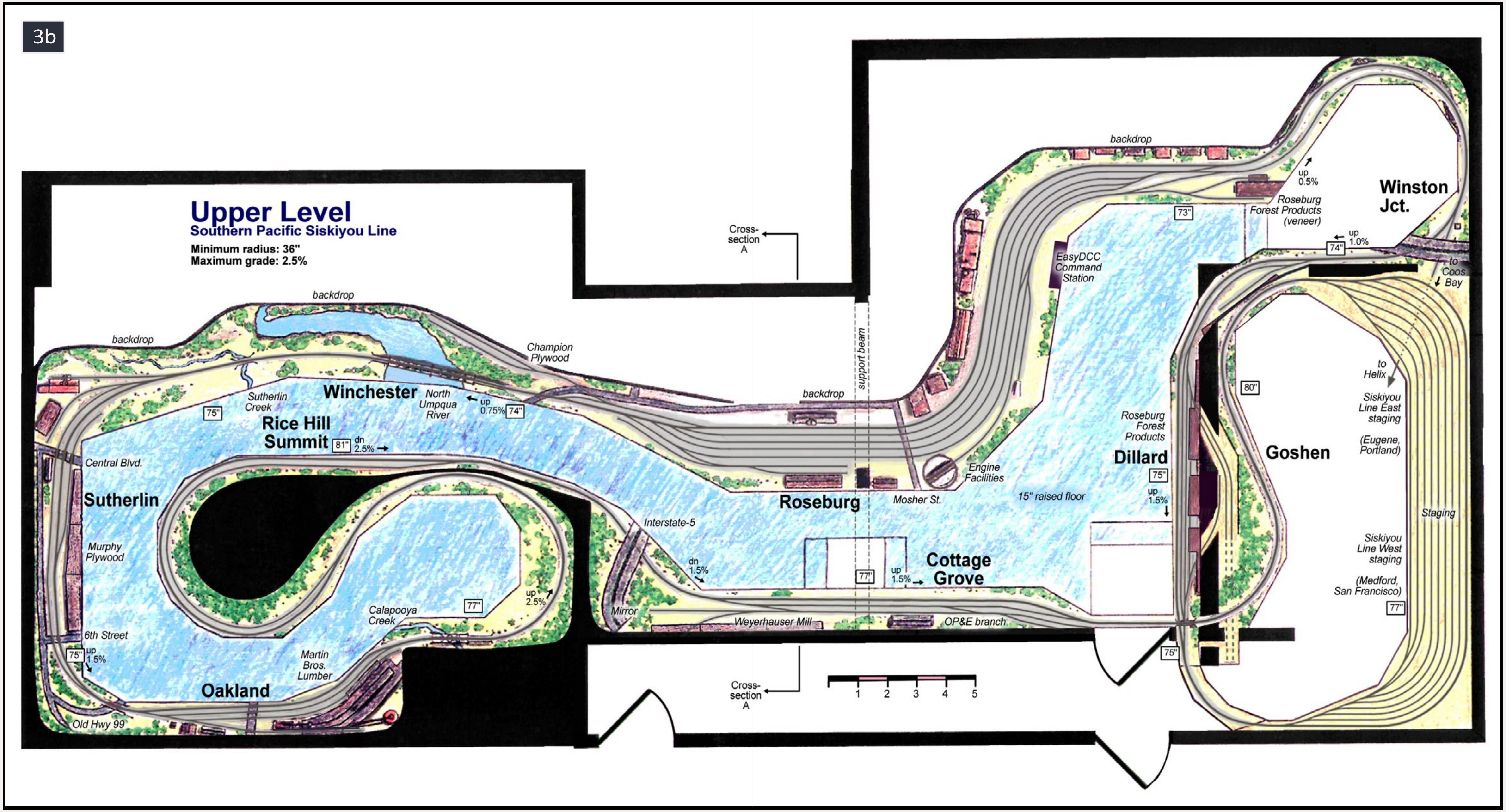
2a: **Lower deck** track plan for Joe Fugate's HO Siskiyou Line.

3a: **Upper deck** track plan for Joe Fugate's HO Siskiyou Line.

Captions continue on the following pages.



2b: Joe Fugate's Siskiyou Line lower level track plan. When Joe designed his multi-deck HO Siskiyou Line, he depended on the operating potential stats for guidance in refining the lower deck Coos Bay branch and showing its weaknesses. Joe adjusted the plan repeatedly using the formulas until he got the results he wanted. Now that the layout has been operational for over a decade, Joe found what the stats predicted has been very close to how his layout actually operates.



3b: Joe Fugate's Siskiyou Line upper level track plan. Joe used the stats in this article to help him design and set the capacity for Roseburg Yard and for his Eugene/Medford staging. Joe has found the number of cars moved and the max cars capacity stats to both be good predictors of actual experience. Also the dispatching threshold applies to the train sizes Joe runs on his layout and predicts the complexity of dispatching based on train size and Joe's varying passing siding lengths.

“Ideally, staging train lengths should more or less equal the corresponding passing train lengths.”

STAGING TRAIN LENGTH (Cars): Write this stat as three values separated by slashes – longest/average/shortest. Longest is the length of your longest staging track in cars. Average is the length an average staging track in cars, computed as: **staging track / number of staging tracks.** Shortest is the length of your shortest staging track in cars.

Ideally, staging train lengths should more or less equal the corresponding passing train lengths. Significantly smaller staging train lengths mean extra switching will be involved in getting a “full length” train into or out of staging. Larger staging train lengths mean full length opposing trains from staging will clog the main. The longer of passing or staging train length should rule in determining typical long train length. The shorter of passing or staging train lengths should rule in determining typical average and short train lengths.

You may notice that staging tracks and passing tracks appear somewhat interchangeable in these formulas. This either/or use of staging and passing sidings reflects an operating session reality (one that was actually exploited by Tony Koester on his AM, by the way) where the layout’s staging can be viewed as “virtual passing sidings”.

For example, the dispatcher could set up a “meet” between opposing trains to occur offstage. To do such a “meet,” one train exits the layout into staging, after which a different train enters the layout – as if a meet had just taken place in an offstage passing siding. If some of the passing sidings on the layout are rather short, this can be a useful technique for arranging meets between longer trains.

OPERATING POTENTIAL

From the basic stats, we can quickly estimate the layout’s operating potential. Way back in June 1968, *Model Railroader* published “Layout plans by formula”, written by Dr. Roy F. Dohn. Dr. Dohn described how to estimate the operating potential of a track plan using some clever formulas he developed by working backwards from actual operating model railroads.

Using his formulas as a starting point, I have developed an updated set of formulas.

MAXIMUM NUMBER OF CARS: A layout can only hold so many cars before it gets difficult to move cars because the destinations are at capacity. This upper limit seems to be around 80% of the total capacity for stationary cars, so we can compute this as: **80% of (storage + staging + passing/2)**.

To allow for more cars on the layout, increase the amount of storage and/or staging track, or to a lesser degree, add some passing track capacity. Generally, passing trackage is not intended to be used as permanent storage, so to indicate that some passing siding capacity could be used as short-term storage, a factor of one half is suggested in the formula.

MAX-TO-MAIN: We can take the max number of cars and compare it to the total mainline car capacity to get a sense of how much mainline running a layout has versus how much non-mainline running (that is, switching) it has. Compute the max-to-main value as: **max nbr of cars / mainline track cars** to get a percentage, with the results meaning:

Percentage	Summary	Comments
Under 50%	Mainline focus	Focus is mainline running; little switching
50 - 80%	Mainline emphasis	High amount of mainline running vs. switching
81 - 120%	Balanced	Mainline running and switching balanced
121 - 150%	Switching emphasis	High amount of switching vs. mainline running
Over 150%	Switching focus	Focus is switching; little if any mainline running

NUMBER OF CARS MOVED: The number of cars moved in a typical operating cycle can be computed as: 4**0% of (staging x 2 + passing + connecting)**. To increase the number of cars moved, we need to increase some combination of staging, passing, or connecting trackage.

Notice staging is particularly effective in increasing the number of cars moved, since for every train that leaves staging, another can move in to replace it, meaning twice the cars can be moved (if they are available elsewhere on the layout). In effect, staging acts as both connecting track and passing track – thus serving double duty.

Another thing we can do to increase cars moved is stop using some track for storage, and designate it instead to be either staging, passing (if trains can legitimately "pass" on this trackage), or leaving it undesignated and always free of stored cars, so by default it becomes connecting track.

TRAINS: We can divide the number of cars moved by our average train length to arrive at the average number of trains we can expect in a typical operating cycle. **Average train length is the smaller of average passing train length or average staging train length**.

One operating cycle is defined as running the layout in a realistic manner until the trains you run begin to repeat. Ordinarily this will be one "24 hour" day according to the modeled train schedule. Depending on our fast clock ratio, the experience of our crew, the reliability of our equipment, the length of a typical run, and the level of detail to which we simulate prototype operating practices, the actual time it takes to complete one cycle could vary from one hour to dozens of hours. Three to four hours is probably a good typical cycle, however.

DISPATCHING THRESHOLD: Compute as: **(3 x shortest passing siding + 2 x average passing siding + longest passing siding) / 6**. Two opposing trains of this size or larger will tend to create a dispatching bottleneck because they cannot easily pass each other except at select sidings. If you want to ease the dispatcher's workload, keep the typical train length at or under this size.

If you want the dispatcher to more easily manage longer trains, then lengthen your passing sidings. The best way to increase this threshold is to lengthen your shortest passing sidings first. Of course, you need to keep the length of your staging tracks in sync with passing siding lengths as explained above under the train length stats.

Another less obvious tactic to improve this stat (if your passing sidings are smaller than your staging tracks) is to declare very short passing sidings to be switching runaround tracks only (and thus connecting track instead of passing track), thereby removing them from routine consideration as locations where the dispatcher might arrange meets. This tactic also has the effect of increasing the number of cars moved since it creates more connecting trackage.

SOME EXAMPLES

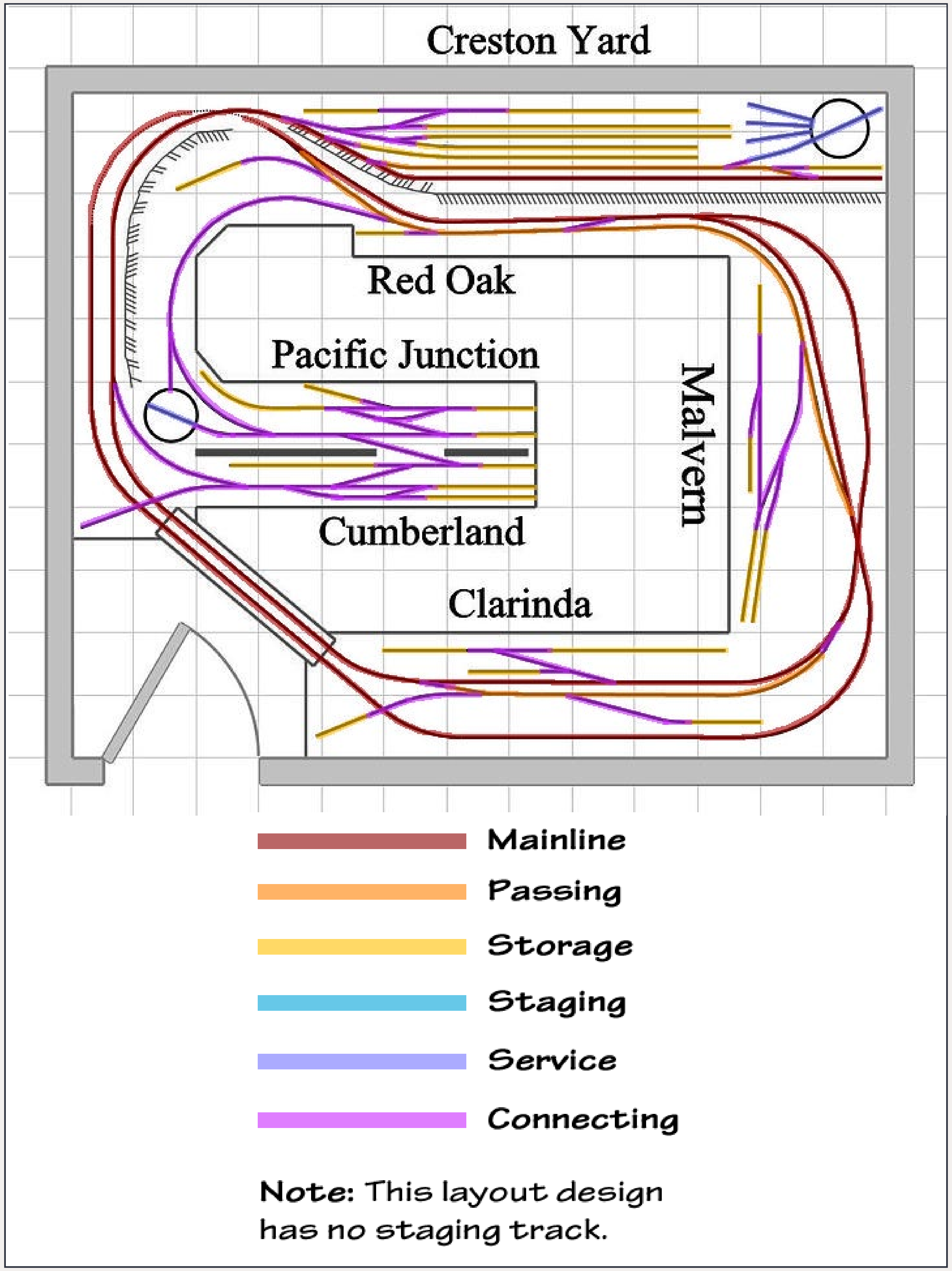
To see how these formulas work, let's take a few track plans from the MRH Trackplan Database thread and run the stats on them. We've included each track plan with the different kinds of track marked so you can see how the track gets categorized.

CB&Q in Iowa (HO)

George Booth posted this plan on the MRH website at: mrhmag.com/track-plan-database?page=1#comment-101734

```
Room area ............... 150 sq ft
Layout area ............. 86 sq ft  (57%)
Number of turnouts ...... 45
Total track ............. 222/444 ft/cars
Mainline track .......... 162 cars
Passing track ........... 54 cars
Storage track ........... 104 cars
Staging track ........... 0 cars
Service track ........... 12 cars
Connecting track ........ 112 cars
Passing sidings.......... 3
Passing length .......... 26/18/14
Staging tracks .......... 0
Staging length .......... 0/0/0

Maximum cars ............ 104 cars
Max-to-main ............. 64%
Cars moved .............. 67 cars
Trains .................. 3.7 (18 cars ea.)
Dispatching threshold ... 17 car trains
```



This track plan has no staging trackage, which makes it something of an "old school" design. It can hold just over 100 cars and move 3-4 trains of about 18 cars each in a session. The layout has 45 turnouts, or about one turnout for every 2 square feet of layout area, which makes the trackwork fairly costly, and also will take a good amount of effort to maintain.

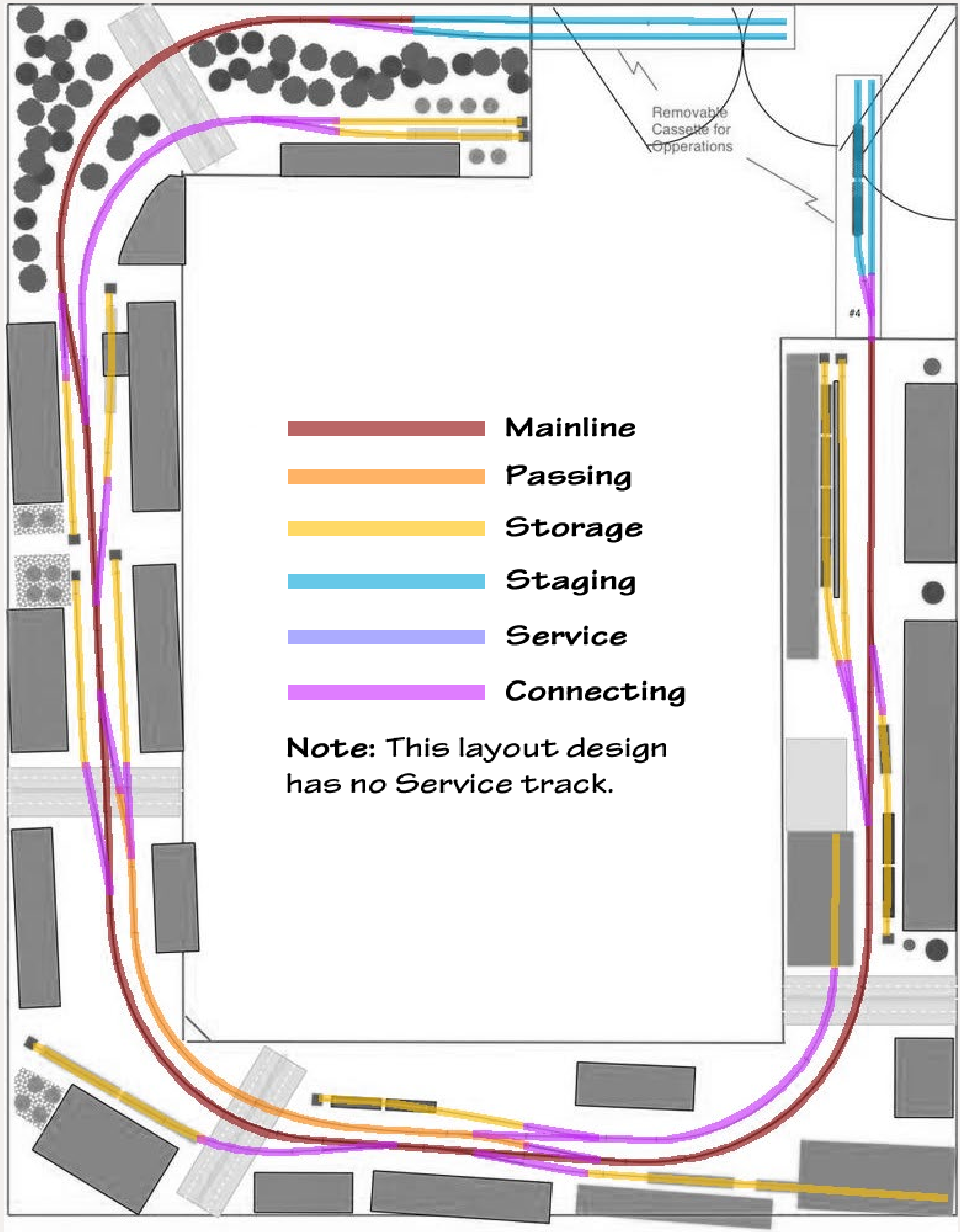
Compare this design to the next one, which is also HO and has an almost identical room square footage.

Illinois Rail (HO)

Richard Johnston posted this plan on the MRH website at:
mrhmag.com/track-plan-database?page=4#comment-102148

```
Room area ............... 148 sq ft
Layout area ............. 73 sq ft (49%)
Number of turnouts ...... 17
Total track ............. 129/358 ft/cars
Mainline track .......... 68 cars
Passing track ........... 16 cars
Storage track ........... 66 cars
Staging track ........... 28 cars
Service track ........... 0 cars
Connecting track ........ 80 cars
Passing sidings.......... 1
Passing length .......... 16/16/16
Staging tracks .......... 4
Staging length .......... 9/7/4

Maximum cars ............ 82 cars
Max-to-main ............. 121%
Cars moved .............. 61 cars
Trains .................. 8.7 (7 cars ea.)
Dispatching threshold ... 16 car trains
```



This track plan can hold just over 80 cars and move 8-9 trains of about 7 cars each. The layout only has 17 turnouts, or about one turnout for every 4 square feet of layout area. This layout is much less dense than the previous CB&Q layout, which will make it a lot cheaper to build a quite a bit less effort to maintain even though both layouts fit in the same square footage of space.

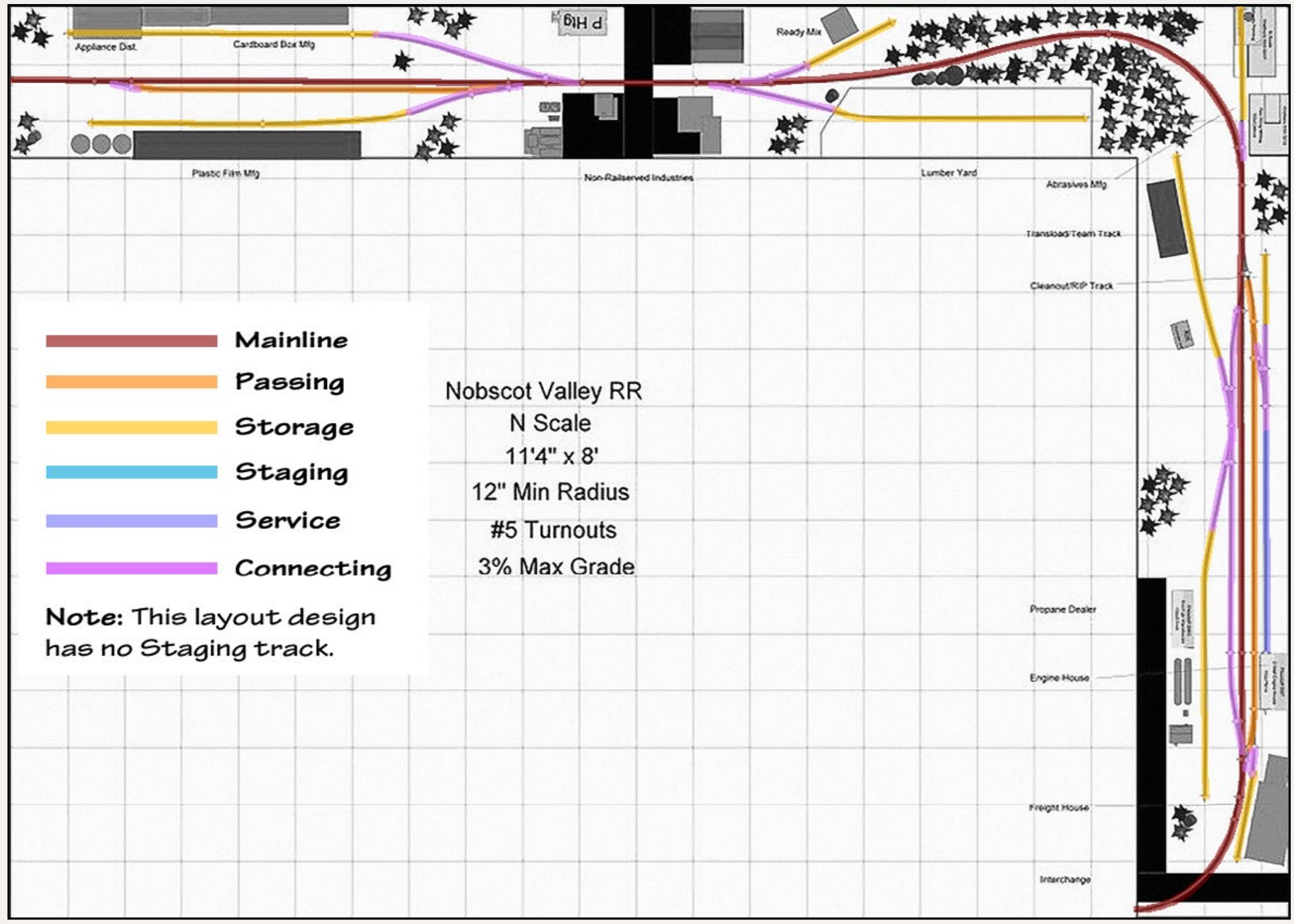
While this layout has one passing siding, it's quite ample at 16 cars. Since staging is limited to 4-9 cars, trains will be shorter than this.

The Nobscot Valley RR (N)

Kevin Theroux posted this plan on the MRH website at:
mrhmag.com/track-plan-database?page=17#comment-159854

```
Room area ............... 56 sq ft
Layout area ............. 27 sq ft (48%)
Number of turnouts ...... 16
Total track ............. 93/372 ft/cars
Mainline track .......... 76 cars
Passing track ........... 60 cars
Storage track ........... 120 cars
Staging track ........... 0 cars
Service track ........... 8 cars
Connecting track ........ 108 cars
Passing sidings.......... 2
Passing length .......... 32/30/28
Staging tracks .......... 0
Staging length .......... 0/0/0

Maximum cars ............ 120 cars
Max-to-main ............. 158%
Cars moved .............. 68 cars
Trains .................. 2.3 (30 cars ea.)
Dispatching threshold ... 29 car trains
```



This layout can hold 120 cars and move 2 trains of about 30 cars each. The design has 16 turnouts, or about one turnout for every 1.5 square feet of layout area (equivalent to 1 turnout per 3 square feet in HO), which makes the density on this layout moderate as to cost and maintenance effort. This plan's turnout density is greater than the Illinois Rail design, but less dense than the CB&Q design.

The typical train length of 30 cars and a dispatching threshold of 29 cars means the dispatcher may find it challenging to get two full-length trains past each other without some planning.

A FINAL EXAMPLE: MY SISKIYOU LINE

Then of course, there's my own HO Siskiyou Line layout. These stats actually reveal some design tricks I used to get everything to fit. Look closely and see if you can spot what I did.

Room area	810 sq ft
Layout area	689 sq ft (85%)
Number of turnouts	122
Total track	1078/2156 ft/cars
Mainline track	706 cars
Passing track	338 cars
Storage track	516 cars
Staging track	336 cars
Service track	18 cars
Connecting track	242 cars
Passing sidings..........	10
Passing length	44/33/12
Staging tracks	11
Staging length	43/30/10
Maximum cars	816 cars
Max-to-main	116%
Cars moved	500 cars
Trains	16.7 (30 cars ea.)
Dispatching threshold ...	22 car trains

The Siskiyou Line was designed for long trains in the spirit of the prototype SP, so the average length train is 30-33 forty-foot cars. Notice the variation between the shorter and longer passing sidings is enough that most trains will exceed the dispatching threshold of 22 car trains. Dispatching this railroad can become a challenge since two average length or longer trains will only be able to meet at a few select passing sidings. However, this little design trick allowed me to squeeze in more towns and still have a reasonable amount of single track between the towns

The mainline length of 706 cars compared to the max car capacity of 816 gives a main-to-max value of 116%. These two values are closely matched, meaning the mainline running and switching are fairly balanced on my layout, with a slight leaning toward switching over mainline running (getting close to the 121% cutover level).

Also notice my layout has an 85% space usage percentage, as compared to the other single deck track plans that all have a space usage of about 50%. Multi-deck designs typically push well beyond 50% space usage, with some triple-deck designs (generally, the third deck is hidden staging) exceeding 100%.

Looking at the maximum cars needed on the Siskiyou Line, one gets faint-hearted realizing 500-800+ cars will be needed for full operation! What have I gotten myself into?

4: Joe has found the formulas and stats shown here that he computed while designing the Siskiyou Line have been proven out in over a decade of op sessions on the Siskiyou Line. Thanks to these formulas, Joe's layout dynamics are pretty much as expected.

SUMMARY FORM

If we were to enhance published track plans with these stats, we can use a summary form, as illustrated here. Taking the example layouts above and condensing their stats down into summary form we have:

```
HO CB&Q in Iowa (George Booth)
         Room area: 150 sq ft
       Layout area: 86 sq ft (57%)
   Number turnouts: 45
       Total track: 222 ft
      Train length: 18 cars
  Maximum capacity: 104 cars
 Main vs switching: Mainline emphasis (64%)
Cars moved/session: 67 cars
            Trains: 3.7
Dispatch threshold: 17 car trains

HO Illinois Rail (Richard Johnston)
         Room area: 148 sq ft
       Layout area: 73 sq ft (49%)
   Number turnouts: 17
       Total track: 129 ft
      Train length: 16 cars
  Maximum capacity: 82 cars
 Main vs switching: Switching ephasis (121%)
Cars moved/session: 61 cars
            Trains: 8.7
Dispatch threshold: 16 car trains

N Nobscot Valley (Kevin Theroux)
         Room area: 56 sq ft
       Layout area: 27 sq ft (48%)
   Number turnouts: 16
       Total track: 93 ft
      Train length: 30 cars
  Maximum capacity: 120 cars
 Main vs switching: Switching emphasis (158%)
Cars moved/session: 68 cars
            Trains: 2.3
Dispatch threshold: 29 car trains

HO SP Siskiyou Line (Joe Fugate)
         Room area: 810 sq ft
       Layout area: 689 sq ft (85%)
   Number turnouts: 122
       Total track: 1078 ft
      Train length: 30 cars
  Maximum capacity: 816 cars
 Main vs switching: Balanced (116%)
Cars moved/session: 500 cars
            Trains: 16.7
Dispatch threshold: 22 car trains
```

As you can see, with these stats, we can truly plan a layout, whether big or small. And we can finally compare layouts quickly in a meaningful way – allowing us to appreciate more than just their good looks. ☑

Reader Feedback (click here)