U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

February 8, 2019

Mr. Jerry C. Boles (via email to: jcb@brs.org)
President
Brotherhood of Railroad Signalmen
917 Shenandoah Shores Road
Front Royal, VA 22630

Mr. Freddie Simpson (via email to: fns@bmwe.org)
President
Brotherhood of Maintenance of Way Employes Division of the IBT
41475 Gardenbrook Road
Novi, MI 48375-1328

Re: Response to Petition for Reconsideration filed in Docket No. FRA-2018-0091; Approval of BNSF Railway Company Test Program to Evaluate Automated Track Inspection Technologies

Dear Messrs. Boles and Simpson:

I write in response to the Brotherhood of Maintenance of Way Employes Division of the IBT (BMWED) and the Brotherhood of Railroad Signalmen's (BRS) (collectively referred to as Petitioners) Petition for Reconsideration, filed in docket number FRA-2018-0091. Petitioners sought reconsideration of the Federal Railroad Administration's (FRA) approval of BNSF Railway Company's (BNSF) Test Program to evaluate automated track inspection technologies and the temporary suspension of 49 C.F.R. § 213.233(c) as necessary to carry out the Test Program. 83 Fed. Reg. 55449 (Nov. 5, 2018). In its Petition, the Petitioners argue that FRA's action amounted to a waiver of 49 C.F.R. § 213.233(c) and accordingly should have followed the waiver procedures outlined in 49 C.F.R. Part 211, Subpart C, and 49 C.F.R. § 213.17. Further, Petitioners allege that even if BNSF's Test Program may be considered under 49 C.F.R. § 211.51 for purposes of a temporary suspension of 49 C.F.R. § 213.233(c), the suspension is not "necessary to the conduct" of the Test Program, 49 C.F.R. § 211.51(a)(1), and is not "conditioned on the observance of standards sufficient to assure safety," *Id.* at § 211.51(a)(3).

After careful consideration of the Petitioners' Petition for Reconsideration, for the reasons detailed below, FRA denies the Petition for Reconsideration.

I. Background

A. General Background on Automated Track Inspection Technology

Automated track inspection technologies have been evolving since the 1970s. With advances in rail safety, the number of track-caused derailments in the United States has steadily decreased since the 1970s, but in recent years, the rate of the decrease has slowed. New and alternative track inspection methodologies and associated technologies are being developed to help continue to drive down the number of track-caused derailments. Technological advancements, including automated track inspection and other emerging technologies, have become a key element of track asset management and safety assurance. For example, in addition to traditional track geometry measurement systems, technologies have now been developed to measure rail profile, while other systems can now measure and monitor ride quality and gage restraint. Ground penetrating radars, track imaging systems, ultrasonic rail flaw detection systems, machine learning-based track component (visual) inspection systems, vertical track deflection systems, and Lidar 3-D scanning systems are all now used to measure various aspects of track health.

Today, every Class I railroad uses some form of automated track inspection for track geometry, rail profile, and/or gage restraint measurement. Track geometry, rail profile and gage restraint measurements are important parameters for assessing the condition of railroad track. Most Class II railroads, and even some smaller railroads, also utilize these types of technologies. FRA, itself, runs a fleet of track inspection cars under its Automated Track Inspection Program (ATIP), conducting compliance surveys over 50,000 to 100,000 miles of track every year.

Automated track inspection systems provide an objective method to evaluate track conditions and to identify defective conditions in the track or conditions that could lead to defects in the track. In addition to these safety benefits, automated track inspection technologies have operational benefits. In contrast to visual inspections by track inspectors, automated inspections can take key measurements continuously and at track speed, allowing the inspection of more track in any given time period, as compared to manual visual inspections by track inspectors. Onboard computers process the enormous amount of raw data in real time and produce concise track condition reports, noting indications of track defects or deficiencies so that track owners can take remedial actions promptly.

Automated track inspection systems typically require substantial investments by the employing railroads. The equipment itself is expensive and requires the use of dedicated manpower. An automated track inspection system typically consists of one or more of the measurement systems mounted on a rail bound vehicle.

Automated track inspection systems may also be autonomous, meaning the highly specialized, automated inspection equipment is mounted to on-track equipment (in some cases revenue trains) and the inspections are conducted with minimal direct human involvement (e.g., unmanned operations). Autonomous track inspection technologies have been developed utilizing revenue service trains equipped with data collection equipment that employ wireless communications to provide inspection data with dramatically increased frequency and reduced cost. By making inspection systems autonomous, the data can be collected more frequently without consuming track time. The goal of autonomous inspection technologies is the earlier detection of track defects and changing maintenance practices from reactive to preventative, ultimately reducing the number of track-caused derailments throughout the railroad industry.

FRA has conducted extensive research on ATGMS and drafted technical documents and summaries on the subject. *See generally* FRA, Autonomous Track Geometry Measurement Technology Design, Development, and Testing (2018), attached as Exhibit 1; Soheil Saadat et al., FRA, FRA Autonomous Track Geometry Measurement System Technology Development – Past, Present, and Future (2014), attached as Exhibit 2; Soheil Saadat et al., FRA, Development and Use of FRA Autonomous Track Geometry Measurement System Technology (2014), attached as Exhibit 3; Cameron Stuart et al., Development of Autonomous Track Geometry Measurement Systems for Overall Track Assessment (2011), attached as Exhibit 4; Gary A. Carr et al., Autonomous Track Inspection Systems – Today and Tomorrow (2009), attached as Exhibit 5.

In 2008, FRA installed an Autonomous Track Geometry Measurement System (ATGMS) on Amtrak's Auto Train route operating between Virginia and Florida. The system detects, locates, and reports potential track defects in near real-time to a web-based inspection data management system for review and remedial action. With the Test Program approved by FRA that is the subject of this decision, BNSF is testing its own ATGMS. FRA is confident that with wider application and more thorough testing of ATGMSs, along with other complimentary technologies (e.g., machine vision or machine learning systems), track inspection efficiency will be significantly improved.

B. Background on BNSF's Test Program

On April 24, 2018, FRA met with BNSF to discuss a proposed Test Program[1] aimed at testing new automated track inspection methodologies. At the meeting, BNSF conducted a presentation in which it laid out a general summary of its proposed Test Program and the reasons why it would improve the quality of track inspections. *See* BNSF Railway, Regulatory Reform (Apr. 24, 2018), attached as Exhibit 6 [Highlighting these as reminders to attach.] During the meeting, BNSF asserted that the current track inspection system, outlined in 49 C.F.R. § 213.233, exposes railroad employees to unnecessary risk. Pursuant to 49 C.F.R. § 213.233, track must be inspected either on foot or in hi-rail vehicles, both of which require the employees to be on or near the track during the inspection. 49 C.F.R. § 213.233(b). BNSF further explained that existing technology can conduct such inspections more efficiently and effectively by reducing safety risk for employees, improving the quality of the inspections, increasing the number of defects detected, and facilitating the development of new automated testing technology. BNSF provided FRA with data supporting its conclusion that increased automated testing would increase safety. *See* Exhibit 6 at p. 9–10.

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[1] Documents referenced in this Response, as well as Exhibits to this Response, may use the term "pilot program" as opposed to the term "test program." For purposes of this Response, the terms are considered synonymous and interchangeable.

At the meeting, BNSF also provided FRA with a draft petition requesting a temporary suspension of 49 C.F.R. § 213.233 to allow for the testing of new automated track inspection methodologies (April 23, 2018 draft Petition). *See* BNSF Petition for a Temporary Suspension of 49 C.F.R. § 213.233 to Allow for the Testing of Automated Track Inspection Methodologies (Apr. 23, 2018), attached as Exhibit 7. BNSF requested that the petition for a temporary suspension be granted under 49 C.F.R. § 211.51, and maintained that the Test Program would increase employee safety, as well as improve the overall quality of track inspections. BNSF proposed general parameters of the Test Program, including geographical limitations, a phased implementation, the utilization of performance-based track-health metrics, and confirmation that necessary adjustments would be made when results were obtained. *See* Exhibit 7.

On June 11, 2018, members of FRA met with BNSF at BNSF's Technical Training Center in Overland Park, Kansas, at which time BNSF made another presentation, provided another copy of its draft petition (now dated June 8, 2018), and the parties discussed the proposed Test Program. *See* BNSF Railway, Regulatory Reform (June 11, 2018); BNSF Petition for a Temporary Suspension of 49 C.F.R. § 213.233 to Allow for the Testing of Automated Track Inspection Methodologies (June 8, 2018), both attached as Exhibit 8.

On July 5, 2018, FRA responded to BNSF's April 23, 2018 draft Petition. *See* Letter from Robert Lauby, Associate Administrator for Railroad Safety and Chief Safety Officer, FRA, to Steve Anderson, Vice President of Engineering, BNSF (July 5, 2018), attached as Exhibit 9. FRA's letter summarized the proposal BNSF submitted and the requirements of 49 C.F.R. § 211.51,[2] and concluded that BNSF's draft Petition lacked sufficient detail to constitute a test program under 49 C.F.R. § 211.51. FRA provided BNSF with a list of potentially relevant information for FRA's further consideration of BNSF's Test Program. It was "intended to provide guidance in BNSF's development of a test program." *Id.* at 2.

On July 31, 2018, BNSF submitted a Petition for a Temporary Suspension of 49 C.F.R. § 213.233(b) and (c) to Allow for the Testing of Automated Track Inspection Methodologies (Petition), which is attached as Exhibit 10. The Petition responded to FRA's July 5, 2018 letter by submitting additional information about the proposed Test Program, including: maps, track charts, and tonnage information on the proposed test area; a table listing the inspection type and frequency for each phase of the Test Program, as well as the metrics to determine the effectiveness of the program; and the reporting requirements.

FRA continued to work with BNSF to address FRA's additional safety concerns with the Test Program and to obtain clarifying information on some of the elements of the Test Program. In response to these discussions, on August 31, 2018, BNSF supplemented and amended its Petition. *See* Letter from John Cech, Vice President of Engineering, BNSF, to Robert Lauby, Associate Administrator Railroad Safety, FRA (Aug. 31, 2018), attached as Exhibit 11. In its letter, and at the request of FRA, BNSF limited the scope of the Petition to

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[2] This regulation provides that first, the suspension must be necessary to the conduct of an FRA-approved "test program designed to evaluate the effectiveness of new technology or operational approaches . . . ." § 211.51(a)(1). Second, the suspension must be "limited in scope and application to such relief as may be necessary to facilitate the conduct of the test program . . . ." § 213.51(a)(2). The third and final requirement mandates that the suspension be "conditioned on the observance of standards sufficient to assure safety." § 211.51(a)(3).

request suspension of 49 C.F.R. § 213.233 (c) (which establishes the frequency of testing normally required), but not, as previously proposed, subparagraph (b) (which requires tests mandated by § 213.233 be performed on foot or by vehicle). BNSF further removed an initially proposed Phase 5 (which would have implemented the Test Program system-wide) and amended the number of geometry and optical tests in Phases 3 and 4 to require a minimum of two per month. Additionally, BNSF tightened the review timeframe for exception reports and the performance metrics for Phases 3 and 4, so that track conditions would be addressed quicker than originally proposed (i.e., within 24 hours, as compared to 48 hours). Finally, at the request of FRA, BNSF provided additional information on the rationale for choosing the proposed route for the Test Program. In sum, these changes clarified the parameters of the automated testing phases of the Test Program and addressed FRA's safety concerns.

On September 26, 2018, after more than five months of discussion and deliberation, FRA approved BNSF's Test Program and suspended the requirements of 49 C.F.R. § 213.233(c), subject to additional conditions, for one year. *See* Letter from Ronald Batory, Administrator, FRA, to John Cech, Vice President of Engineering, BNSF (Sept. 26, 2018), attached as Exhibit 12. FRA's letter concluded that the Test Program would consist of BNSF's July 31, 2018 Petition, along with the included exhibits, *see* Exhibit 10, as well as the August 31, 2018 letter from BNSF, *see* Exhibit 11, which supplemented and amended the Petition. In its September 26, 2018 approval letter, FRA concluded that it was necessary to suspend 49 C.F.R. § 213.233(c) while BNSF conducted its Test Program, *see* Part II.B below for additional discussion of this issue, and FRA imposed 12 conditions on BNSF. These conditions, combined with the conditions specified in BNSF's Test Program, were designed to both ensure safety and allow the Test Program to determine the effectiveness of BNSF's new approach to track inspections.

On October 19, 2018, following additional discussions between BNSF and FRA, BNSF sent a clarifying letter to FRA. *See* Letter from John Cech, Vice President of Engineering, to Robert Lauby, Associate Administrator for Railroad Safety, FRA (Oct. 19, 2018), attached as Exhibit 13. This letter explained the inspection frequency for rail joints and turnouts, as well as stating that geometry car testing could include manned track geometry cars. On October 24, FRA replied to BNSF's clarifying letter and stated it had no objection to BNSF's clarifications or modifications. *See* Letter from Thomas Herrmann, Director, Office of Technical Oversight, FRA, to John Cech, Vice President of Engineering, BNSF (Oct. 24, 2018), attached as Exhibit 14.

II. Issues Raised by the Petition for Reconsideration

A. FRA Followed the Proper Procedures When Granting BNSF's Test Program

Petitioners argue that FRA's actions approving the Test Program amount to a waiver of 49 C.F.R. § 213.233(c) and should, accordingly, have complied with the waiver procedures outlined in 49 C.F.R. Part 211, Subpart C, and 49 C.F.R. § 213.17. FRA disagrees. 49 C.F.R. § 211.51(a) provides that FRA "may temporarily suspend compliance with a substantive rule of the Federal Railroad Administration," provided it meets three conditions. First, the suspension must be necessary to the conduct of an FRA-approved "test program designed to evaluate the effectiveness of new technology or operational approaches . . . ." 49 C.F.R. § 211.51(a)(1). Second, the suspension must be "limited in scope and application to such relief as may be necessary to facilitate the conduct of the test program . . . ." *Id.* at § 213.51(a)(2). The third and final requirement mandates that the suspension be "conditioned on the observance of standards sufficient to assure safety." *Id.* at § 211.51(a)(3).

The procedures under 49 C.F.R. § 211.51 are clearly standalone procedures that permit FRA to suspend compliance with specific FRA regulations so that an approved test program may be conducted. Petitioners do not argue otherwise. While the effect of a suspension under 49 C.F.R. § 211.51 may be similar, or in some cases identical, to a waiver under 49 C.F.R. Part 211, Subpart C, and 49 C.F.R. § 213.17, that fact alone does not support Petitioners' conclusion that FRA was required to utilize the waiver procedures. Waiver procedures apply to far more situations than just test programs, whereas 49 C.F.R. § 211.51 applies specifically to test programs. A regulated entity may elect to apply for a waiver in order to conduct a test program, but absent such an application, FRA is clearly permitted to utilize the procedures under § 211.51 to suspend compliance with a specific rule in order for the applicant to conduct an FRA-approved test program.

Further, Petitioners have presented no evidence they were in any way harmed by FRA's decision to grant BNSF's Test Program pursuant to 49 C.F.R. § 211.51. In the Petition for Reconsideration, Petitioners erroneously state that "the waiver cannot be done without compliance with the procedures of Section 211.41 and 211.43, with advance public notice and opportunity for comment and FRA consideration of those comments." Petition for Reconsideration, at 5. First, this provision applies to waivers and not suspensions under § 211.51. Second, it does not require notice in the *Federal Register* and comment in all waiver proceedings. In fact, 49 C.F.R. § 211.41 instead states that "if required by statute or the Administrator or the Railroad Safety Board deems it desirable, a notice is published in the *Federal Register*, an opportunity for public comment is provided, and a hearing is held in accordance with § 211.25, before the petition is granted or denied." Public notice in the *Federal Register* and an opportunity for comment are not requirements under FRA's waiver procedures, and unless required by statute, they are undertaken solely at FRA's discretion.

Moreover, the regulation at issue does not require that FRA seek public comment on a request for a rule suspension. Rather, the regulation specifically states that "[w]hen the FRA Administrator approves suspension of compliance with any rule in connection with a test program, a description of the test program containing an explanatory statement responsive to paragraph (a) of this section is published in the *Federal Register*." 49 C.F.R. § 211.51(c). Here, FRA's notice published in the *Federal Register* satisfied this regulatory requirement. *See* 83 Fed. Reg. 55449 (Nov. 5, 2018).

Thus, FRA finds no merit to Petitioners' argument that the lack of a public hearing and opportunity to comment is a basis for granting the Petition for Reconsideration.

B. Suspension of 49 C.F.R. § 213.233(c) for BNSF to Conduct the Test Program Is Necessary

Petitioners argue that it is not, as required by 49 C.F.R. § 211.51(a)(1), necessary to suspend compliance with 49 C.F.R. § 213.133(c) in order for BNSF to conduct the Test Program. FRA disagrees. The purpose of the Test Program is to test the effectiveness of new track inspection methodologies, meaning new combinations of visual and automated inspections at different frequencies. As discussed in Part I.A above, FRA has already seen the safety and operational benefits of using automated track inspection technologies and data has shown that automated inspection technology is more effective in detecting track geometry conditions. Furthermore, evidence suggests that these new methodologies may be as or more effective at detecting track defects while also decreasing service interruptions and reducing safety risks to railroad employees. *See* Exhibit 6 at p. 9–10; *see also* Part I.A above. Thus, the various phases of this Test Program are specifically structured so that FRA can collect data that ultimately may help determine whether a specific combination of visual and automated inspections produces the greatest results for both safety and operational benefits. It is not possible to test the effectiveness of such new methodologies if current inspection practices are conducted alongside the Test Program.

As mentioned above, the phased approach of the Test Program is meant to provide data on the effectiveness of different combinations and frequencies of automated testing and visual inspections and to ensure that each phase of the Test Program results in continuous safety improvement before moving to the next phase. To accomplish this, Phase 1 of the Test Program adds automated testing to the currently required visual inspections. Once Phase 1 is complete, the following phases slowly reduce the visual inspections, down to twice monthly on mainline track, while adjusting the combination of automated technology and in some cases the frequency of automated testing. *See* Exhibit 10. Specific metrics measuring how effective each phase's particular combination of inspections is at detecting and preventing the development of defects must be met before BNSF can progress to the next phase of the Test Program. *See* Exhibit B of Exhibit 10.

In order for the Test Program to function as intended, and provide the type of data it is meant to provide, the visual inspection frequency required by 49 C.F.R. § 213.233(c) must be suspended. As discussed below in Part II.C, FRA is confident that the conditions and standards that are required are sufficient to assure continued safety under the Test Program. FRA and BNSF are also able to review the metrics at each phase and determine the effectiveness of the inspection methodology. *See id.* In the event of unforeseen safety risks, FRA will alter or terminate the Test Program, as appropriate.

C. The Test Program Contains Conditions to Ensure Safety during the Suspension of 49 C.F.R. § 213.233(c)

Petitioners allege that FRA's letters approving the Test Program are not publicly accessible and that a reduction in the frequency of manual visual inspections by track inspectors inherently means that safety will be compromised. FRA does not agree. First, as stated in the notice published in the *Federal Register*, a copy of FRA's letters approving BNSF's Test Program were made available in the public docket. 83 Fed. Reg. 55449, 55450 (Nov. 5, 2018). These documents were uploaded to the public docket on *www.regulations.gov* (docket no. FRA-2018-0091) on November 6, 2018.

Second, Petitioners' argument that reductions in the frequency of inspections will inherently compromise safety is premised on the unstated assumption that automated inspections are not superior at detecting defective conditions and degrading conditions. However, automated inspections have proven to be significantly more effective at detecting and measuring geometry conditions, detecting far more defects per inspection mile. *See* Exhibit 6 at p. 10. While FRA acknowledges that the automated inspection technology does not inspect for every condition covered by 49 C.F.R. Part 213, for example, vegetation, crossties, and ballast, it is confident that the continued visual inspections in the Test Program (though at reduced frequencies) will still be able to detect those conditions before they pose a safety risk. Additionally, crosstie and ballast defects generally include a change in track geometry, which is detectable by the automated inspections. Moreover, as discussed in Part II.B above, FRA and BNSF will review the metrics at each phase and determine the effectiveness of the inspection methodology, altering or terminating the Test Program, as appropriate.

Third, in addition to the conditions already in BNSF's Test Program, FRA imposed 12 additional conditions (summarized below), many of which were aimed primarily to further ensure the safety of the Test Program. *See* Exhibit 12. FRA reserves the right to include one of its ATIP cars along with BNSF's geometry car and conduct additional audits at any time. FRA requires that prior to beginning Phase 3, BNSF must detail the methodology for implementing data-driven, focused visual inspections to ensure relevant track components are inspected. FRA further requires BNSF to monitor and measure the effectiveness of the Test Program using the metrics outlined in the Test Program, and revise the Test Program if those metrics cannot be achieved. FRA mandates that BNSF provide calibration procedures and frequencies for the automated testing equipment, have at least 10 calendar days between the twice-monthly visual inspections in Phases 3 and 4, and, if any track segment is not inspected per the schedule in the Test Program, it must be inspected in accordance with 49 C.F.R. § 213.233. Finally, BSNF must report all track-cause derailments that occur on the segments covered by the Test Program to FRA, submit monthly data on inspections and the related inspection reports, and provide records detailing BNSF's track maintenance and repair work.

Finally, the Test Program is limited in geographical scope, consisting of portions of seven subdivisions on BNSF's Powder River Division. The area chosen for the Test Program serves mainly coal unit trains, does not contain passenger traffic, and is a reasonable proxy for the entire BNSF system that could indicate the success of the results of the Test Program system-wide. *See* Exhibits 10 and 11. The elimination of any potential danger to passengers was an important consideration for FRA in the initial approval of this Test Program.

D. The Test Program's Suspension of 49 C.F.R. § 213.233(c) Is Limited in Scope and Application

While Petitioners do not argue that the suspension is not "limited in scope and application to such relief as may be necessary to facilitate the conduct of the test program . . . .[,]" 49 C.F.R. § 213.51(a)(2), FRA takes this opportunity to further explain how the suspension of 49 C.F.R. § 213.233(c) is narrowly tailored in scope and application. As explained in Part II.B above, it is necessary to suspend the minimum required visual inspections in order to conduct the Test Program. This suspension was limited specifically to 49 C.F.R. § 213.233(c), which prescribes the minimum frequency of visual inspections for main track, sidings, and other than main track. Exhibits 11 and 12. FRA did not suspend other inspections required under 49 C.F.R. Part 213. For example, 49 C.F.R. § 213.235 requires additional inspections of switches and track crossings; § 213.237 requires internal rail inspections; and § 213.239 requires special inspections in the event of certain occurrences that might damage track structures, such as floods and severe storms. These requirements are still in place under the Test Program.

Additionally, the suspension of 49 C.F.R. § 213.233(c) was limited in geographical scope to a specific area. The area covered by the Test Program and suspension consists of portions of seven subdivisions on BNSF's Powder River Division. *See* Exhibit 10. At FRA's request, BNSF provided justification for choosing this geographical area. *See* Exhibit 11. As discussed above, the area chosen for the Test Program serves mainly coal unit trains, does not contain passenger traffic, and is a reasonable proxy for the entire BNSF system that could indicate the success of the results of the Test Program system-wide. *See* Exhibits 10 and 11. FRA is confident that the suspension is sufficiently limited in both scope and application to ensure it only provides the relief necessary to conduct the Test Program.

III. Conclusion

In conclusion, it is FRA's judgment that Petitioners do not state a valid basis for changing FRA's decision to approve BNSF's Test Program to evaluate automated track inspection technologies and temporarily suspend 49 C.F.R. § 213.233(c), as necessary to carry out the Test Program. Accordingly, pursuant to 49 C.F.R. § 211.31, FRA hereby denies the Petition for Reconsideration.

FRA will also post this decision and all exhibits to the docket for this proceeding on regulations.gov (FRA-2018-0091). As the exhibits were too large to send

Sincerely,

Robert C Lauby

Robert C. Lauby
Associate Administrator for Railroad Safety and Chief Safety Officer

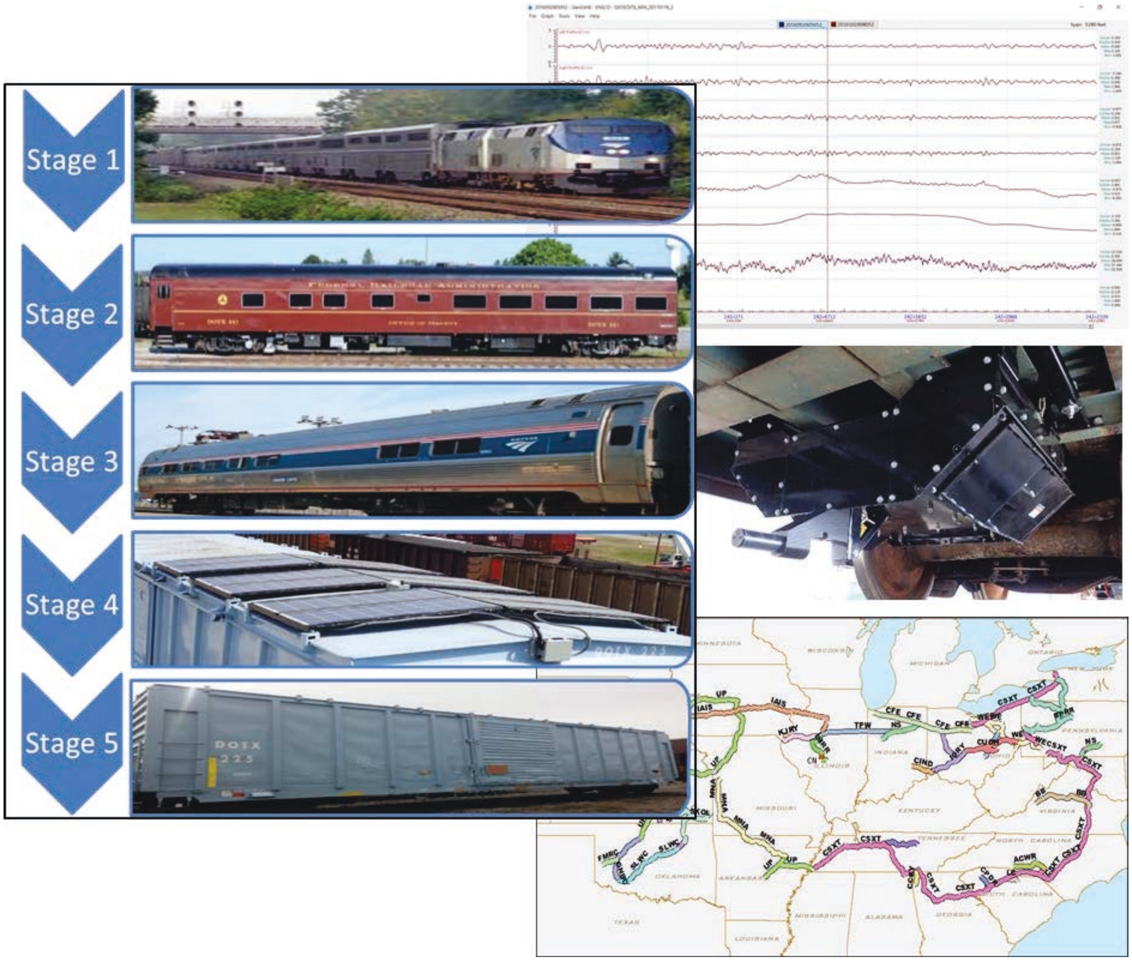
Exhibit 1

U.S. Department of
Transportation

**Federal Railroad
Administration**

Autonomous Track Geometry Measurement Technology Design, Development, and Testing

Office of Research,
Development
and Technology
Washington, DC 20590



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Final Report
March 2018

REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words)

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology has long advocated for the development and advancement of autonomous track geometry measurement systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data. FRA's ATGMS research program has demonstrated the potential benefits and uses of the unmanned inspection approach as well as the requirements for information management. This report provides an overview of FRA's ATGMS research and development program with emphasis on its evolution from a proof-of-concept prototype to a fully operational measurement system. The report also provides a summary of lessons learned from the development of this approach and highlights FRA's vision for the role of autonomous technology in track inspection and safety assurance.

14. SUBJECT TERMS
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298-102

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg)
= 1.1 short tons

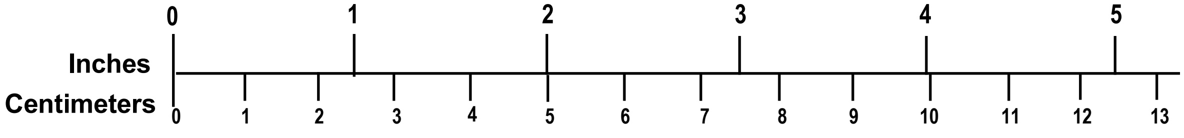
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

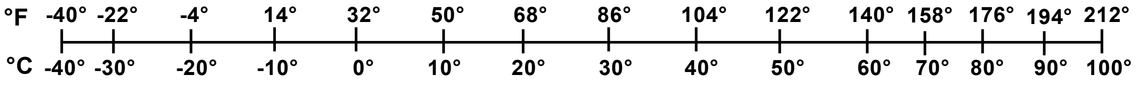
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Acknowledgements

The implementation of this technology could not have taken place without the essential logistical and in-kind support of both CSX Transportation (CSX) and the National Railroad Passenger Corporation (Amtrak) to facilitate both short-term and long-term pilot studies at critical times within the research program. The authors would like to thank Mr. Ron Bright and Mr. Larry Biess of CSX, as well as Mr. Paul Steets and Mr. Mike Trosino of Amtrak for their efforts to facilitate this important research.

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Executive Summary

This report documents the Federal Railroad Administration's (FRA) Office of Research, Development and Technology's (RD&T) successful development and demonstration of autonomous track geometry measurement system (ATGMS) technology. FRA is currently developing autonomous inspection technologies with the objective of improving railroad safety through enhanced conditional awareness. Autonomous track inspection is a process of inspecting the track from revenue trains using unattended instruments, with minimal direct involvement from operators. This technology allows dramatically increased inspection frequencies at reduced cost, when compared to traditional manned methods. Widespread use of autonomous inspection technology has the potential to increase the timeliness of track defect detection and remediation, thus improving the safety of the nation's rail system.

FRA's Office of Railroad Safety (RRS) currently uses ATGMS as part of its ongoing track geometry inspection operations. This transition of ATGMS to routine assessments as part of FRA's Automated Track Inspection Program (ATIP) has yielded positive outcomes for RRS, including an increase in inspection frequency with no reduction in data quality.

In addition to describing the development of the measurement system, this report includes an overview of technologies developed in support of ATGMS operation, including automatic filtering of track geometry defects, track determination and track degradation algorithms as well as remote data editing capabilities. Supplemental material providing details of various development efforts is provided in the appendices of this report.

1. Introduction

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) focuses on the development of new track inspection methods to enhance railroad safety and reduce in-service track failures. Today, the predominant methods for track assessment rely on visual inspection by track inspectors and automated measurement of track geometry from dedicated inspection vehicles. In the case of automated track inspection, these measurement systems are installed on dedicated inspection vehicles and operated by trained personnel. Automated inspections typically require scheduled track time as well as expensive systems and dedicated manpower.

FRA is currently developing autonomous inspection technologies with the objective of improved railroad safety through enhanced conditional awareness. Autonomous track inspection is a process of inspecting the track from revenue trains using unattended instruments, with minimal direct involvement from operators. This technology would allow for dramatically increased inspection frequencies at reduced cost, when compared to traditional methods. Widespread use of autonomous inspection technology has the potential to increase the timeliness of track defect detection and remediation, thus improving the safety of the nation's rail system.

1.1 Background

Autonomous rail vehicle performance measurement and track condition monitoring technology has been in development for many years. The use of an Autonomous Ride Monitoring System (ARMS) on Acela high-speed train sets, operated by Amtrak on the Northeast Corridor (NEC), was the first systematic implementation of un-manned track evaluation in the U.S. This system was based on technology developed by FRA's RD&T and ENSCO, Inc. The performance of the Acela high-speed train sets from a vehicle/track interaction perspective is monitored remotely through automated analysis of the measured carbody and truck vertical and lateral accelerations. The system identifies and reports track conditions of concern and/or poor performing vehicles for corrective actions.

The Maryland Transit Administration's (MTA) Maryland Area Regional Commuter (MARC) service became the second passenger railroad in the United States to equip a number of its trains with a similar system in 2002. In 2004, the Union Pacific Railroad (UP) became the first freight railroad in the United States to adopt the use of similar technology. ARMS units were augmented with axle-mounted accelerometers to identify battered joints, misaligned switches, damaged frogs, and other high-impact events. More than 200 systems of this design, known as Vehicle/Track Interaction (V/TI), are currently in use across Class I U.S. railroads [1].

The effectiveness of autonomous inspection technology by Amtrak, MTA, and UP prompted other industry service providers to develop variations of the technology; while unattended systems that record track geometry data were introduced in Europe in the early 2000s [3]. Based, in part, on the performance of these early systems, FRA recognized a need to provide the railroad industry with advances in technology to improve track inspection by reporting conditions to stakeholders in near real-time using relatively low-cost, modular system designs. Improving the accuracy and timeliness of track geometry data while reducing the life-cycle cost of track geometry systems and operations to encourage widespread adoption of the measurement technology is a key factor in achieving FRA's safety goals.

Track geometry is typically measured using a non-contact approach employing inertial and optical measurement principles. As illustrated in Figure 1, inertial sensors located within a beam mounted to the underside of a rail vehicle are used to locate a measurement reference frame, in this case the beam, in space relative to the track. Laser scanning sensors mounted to the beam are then used to determine the lateral and vertical location of the rails relative to the beam. A laser illuminates the rail and the light scatter highlights the rail's contour in a measurement plane; a camera images the laser light scatter and the x-y coordinates of the rail contour are determined. These coordinates are then combined with measurements made with the inertial sensors using a variety of methods to arrive at traditional track parameters such as gage, profile/surface, alignment, crosslevel and curvature.

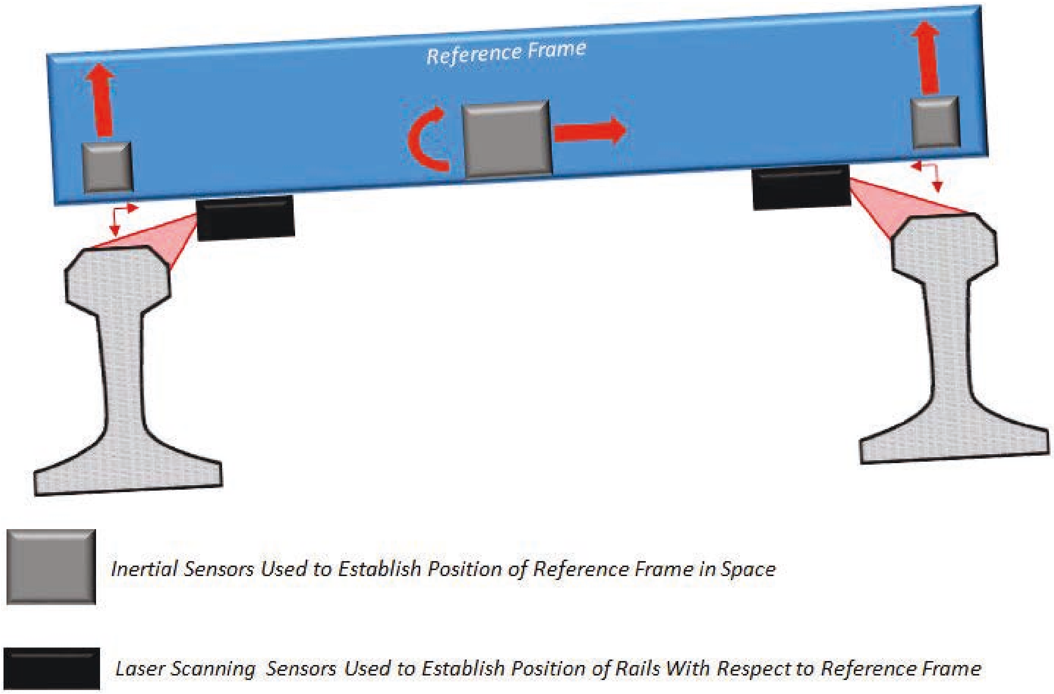


Figure 1: General Approach to Track Geometry Measurement

1.2 Objectives

FRA's RD&T began a multi-stage research program with the objective of developing an autonomous track geometry system to improve rail safety. FRA's vision was to create a relatively low-cost, unattended, self-powering geometry measurement system deployable on standard rail equipment, including freight cars, to collect and distribute accurate track geometry data in a time-efficient manner while running in a standard revenue train. Key aspects of this vision are an ATGMS that:

- Reduces life-cycle costs of geometry measurement operations
- Eliminates interference with revenue operations
- Increases inspection frequencies
- Provides high-quality data

The expected benefits of this approach are highlighted by an increase in the availability of track geometry data for safety and maintenance planning purposes, including the near real-time detection and reporting of exceptions to geometry thresholds and the identification of locations of areas with degraded track geometry.

The objective of the program was not to eliminate human inspection, or to replace manned automated inspection systems as a quality assurance method. FRA's goal was to create a more flexible, efficient tool for use in day-to-day quality control and maintenance planning activities.

1.3 Overall Approach

This report documents the FRA's successful development and demonstration program for autonomous track geometry measurement system (ATGMS) technology. Begun in 2006, the research program was organized into the following five development phases:

Stage 1: Long-Term Pilot with Standard Inspection Technology - The initial stage of development centered on the creation of a ruggedized pilot system using commercial off-the-shelf equipment to facilitate early evaluation. ENSCO developed the basic elements of an autonomous system during this stage with an emphasis on communication and processing software, including preliminary analysis tools. FRA and ENSCO partnered with Amtrak and CSX Transportation (CSX) to install the first ATGMS on an Amtrak Superliner II in revenue service operations as part of Amtrak's Auto Train service between Lorton, VA, and Sanford, FL, over CSX-owned track. The pilot system operated for close to 460,000 miles during this development stage.

Stage 2: Simulation of Standard Revenue Operations - The goal of this development stage was to test the extended range performance of the ATGMS and to verify the quality of ATGMS data by direct comparison with data gathered from a manned geometry car operating in the same consist. An ATGMS was installed on FRA's DOTX 221 passenger car and operated in consist with FRA's Automated Track Inspection Program's (ATIP) DOTX 220 manned inspection vehicle during surveys conducted over Amtrak passenger routes between fall 2011 and spring 2013.

Stage 3: Advanced Measurement Technology Development - The goal of this development stage was to engineer a new ATGMS configuration suitable for mounting directly to a carbody. To demonstrate and evaluate this approach, a carbody-mounted ATGMS was designed, constructed and installed on an Amtrak Amfleet coach, and operated in Amtrak revenue service along the NEC during 2012 and 2013.

Stage 4: Energy Harvesting Technology Development - This stage targeted the evaluation of technology that facilitates ATGMS use in a freight environment. For freight operation, ATGMS needs a dedicated source of power. Researchers considered solar, wind, fossil fuel, and fuel cell-based power sources during this effort. Fossil fuel was initially identified as the most feasible primary source of power for ATGMS, and a review of commercially available diesel generators resulted in a list of technical and operational specifications for a candidate diesel generator. ENSCO also evaluated methanol fuel cells. Historical data on solar power systems installed on railcars indicated that solar power can be effectively used as a source of power. Testing of prototype devices for wind power generation indicated that wind power is not a viable option for a secondary source of power generation because of nominal train speeds in freight operations.

Potential power sources were examined under different operational and environmental conditions to identify optimum configurations for deployment on an unattended rail vehicle.

Stage 5: Demonstration in Freight Service - The final stage of FRA's ATGMS development plan was a demonstration in normal freight service operation. ATGMS technology was demonstrated on a freight vehicle operating in typical revenue service to establish a vision for the use of this track assessment technology throughout the industry. FRA deployed its carbody-mounted ATGMS on a refurbished boxcar as part of a demonstration program conducted over 29 railroads, including 25 short line and regional railroads, between April 2016 and January 2017. Power systems specified during Stage 4 activities were installed on the boxcar to provide continuous power for the system. Data produced from the surveys was provided to the surveyed railroads in several forms to meet the individual railroads' needs.

1.4 Scope

The scope of this research included all aspects of research, technical development, testing, and system demonstration. The multi-phased approach to the work helped to guide the effort through logical, evolutionary steps. Each step in the process established a higher level of capability for the system progressing the technology towards the goal of full autonomy.

1.5 Organization of Report

This report is structured into five sections.

Section 1 documents the introduction and background of the ATGMS technology, as well as introducing the research program's overall approach.

Section 2 provides a synopsis of FRA's approach to the development of ATGMS technology, including an explanation of FRA's five-stage development plan and a description of FRA's current implementation of autonomous inspection.

Section 3 details key advancements in FRA's ATGMS technology, including major accomplishments and findings of each development stage.

Section 4 summarizes the consideration of analyses and processes that are crucial to the implementation of ATGMS, including geometry defect review and filtering, individual track determination and degradation analysis.

Section 5 summarizes conclusions from FRA's development and demonstration efforts and perspectives on the use of unmanned inspection technology in the rail industry.

Supplemental material providing details of various development efforts is provided in the appendices of this report. These appendices are as follows:

- Appendix A – ENSCO Document SERV-REPT-0000507 "Comparison of DOTX221 ATGMS and DOTX220 TGMS Geometry Exceptions and Foot-by-Foot Geometry Summary Report."
- Appendix B – ENSCO Document SERV-REPT-0000578 "DOTX221 ATGMS Operations Performance Report: Summer/Fall 2013 ATIP Amtrak Assessment Survey."

- Appendix C – ENSCO Document SERV-REPT-0000528 “Comparison of Track Geometry Measured with a Carbody-Mounted ATGMS and Amtrak 10002 Summary Report.”

2. ATGMS Research Approach

2.1 Technology Development Plan

FRA's RD&T established a five-stage technology development plan to transition ATGMS technology to the railroad industry. The five stages are depicted in Figure 1 and described below.

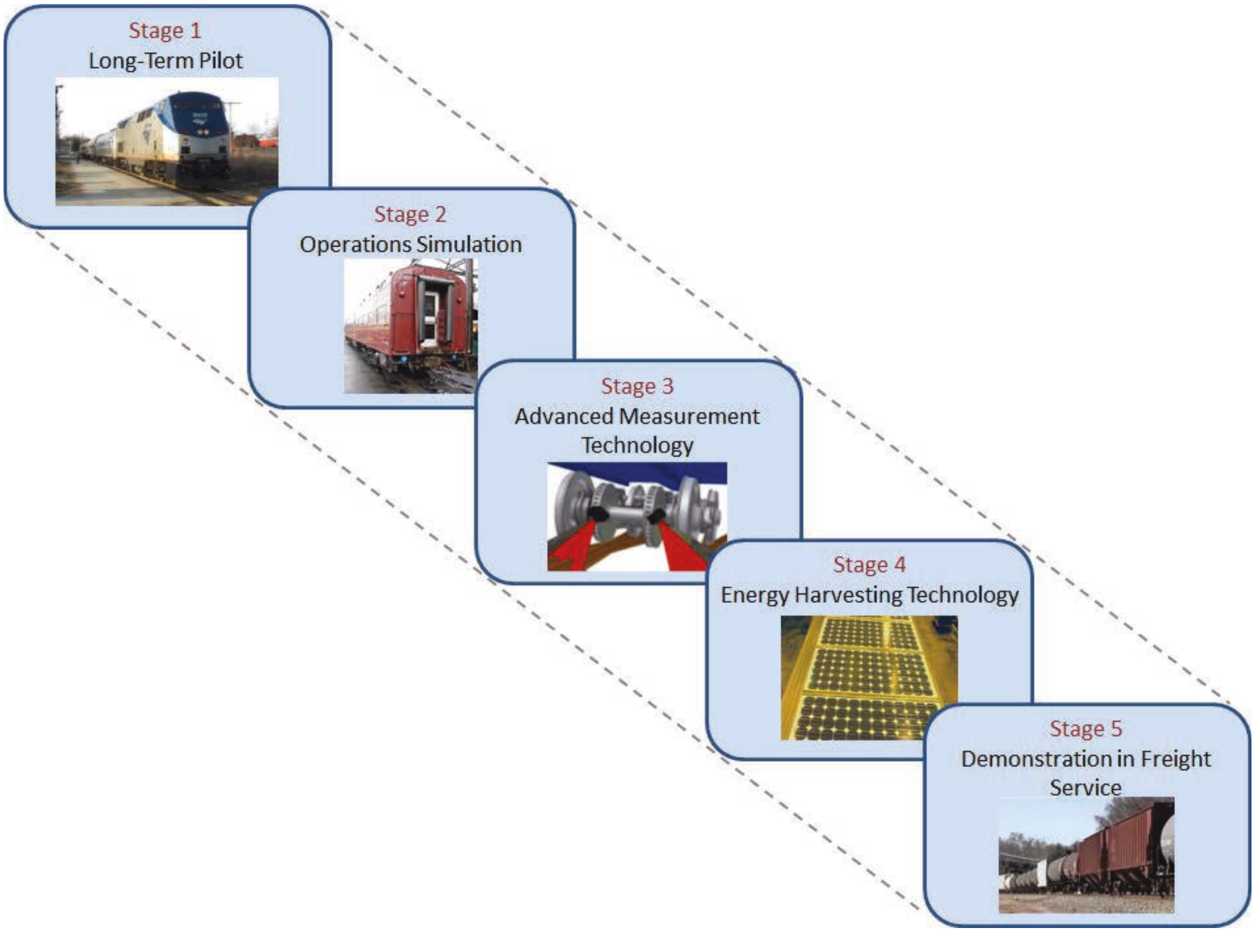


Figure 2: ATGMS Research Stages

Stage 1: Long-Term Pilot with Standard Inspection Technology

The initial stage of development was centered on the creation of a ruggedized pilot system using commercial off-the-shelf equipment to facilitate early evaluation. ENSCO developed the basic elements of an autonomous system during this stage with an emphasis on communication and processing software, including preliminary analysis tools.

This stage included an evaluation of various measurement approaches using a truck-mounted pilot system to identify operation and maintenance issues that resulted from long term, unmanned operations. FRA and ENSCO partnered with Amtrak and CSX to install the first ATGMS on an Amtrak Superliner II in revenue service operations as part of Amtrak's Auto Train service between Lorton, VA, and Sanford, FL, over CSX-owned track. The pilot system operated for close to 460,000 miles during this development stage.

This pilot ATGMS used standard geometry system components typically found on automated track geometry measurement systems. ENSCO configured the system to automatically transmit track geometry exception data, vehicle Global Positioning Satellite (GPS) location coordinates, and vehicle speed information via a standard cellular communications transceiver. Early versions of automated exception filters were employed in an effort to eliminate false alarms.

Stage 2: Simulation of Standard Revenue Operations

The goal of this development stage was to test long distance performance and to verify the quality of ATGMS data by comparison with data gathered from a manned geometry car operating in the same consist. This research simulated a routine operating condition, covering over 30,000 test miles.

ENSCO completed extensive refinements to ATGMS hardware and software systems as part of this development effort. The system was modified to allow for near real-time delivery of raw foot-by-foot sensor data from ATGMS to a central server via commercial cellular service. FRA's ATGMS was transferred to FRA's DOTX 221 passenger car and operated in consist with FRA's ATIP's DOTX 220 manned inspection vehicle during surveys conducted over Amtrak passenger routes between fall of 2011 and spring of 2013. Operation of ATGMS in conjunction with manned track geometry surveys allowed direct comparison of measurements collected with both systems to identify and address any remaining issues affecting data captured by the autonomous system. Detailed results of comparisons conducted in Stage 2 are provided in Appendices A and B.

Stage 3: Advanced Measurement Technology Development

The goal of this development stage was to engineer a new ATGMS configuration suitable for mounting directly to a carbody. Moving the system from a truck-mounted configuration to a carbody-mounted position provides numerous advantages, including a less severe shock-and-vibration environment, reduced exposure to mud, snow, and flying ballast, and less manual interaction with the system during periodic truck maintenance activities. System complexity and construction costs are also reduced, and ATGMS becomes a modular system with a simple interface to the carbody.

A key element of this stage was a demonstration in revenue service operations and a comparison of autonomously collected data that was captured by standard geometry systems. To demonstrate and evaluate this approach, a carbody-mounted ATGMS was constructed and installed on an Amtrak Amfleet coach, and operated in Amtrak revenue service along the NEC during 2012 and 2013. ENSCO compared the performance of the carbody mounted ATGMS to that of the system on Amtrak's 10002 manned geometry car over multiple runs. Appendix C contains results of this comparison.

Stage 4: Energy Harvesting Technology Development

This stage targeted the evaluation of technology that facilitates ATGMS use in a freight environment. For freight operation, ATGMS needs a dedicated source of power. Fossil fuel was initially identified as the most feasible primary source of power for ATGMS, and a review of commercially available diesel generators resulted in a list of technical and operational specifications for a candidate diesel generator. ENSCO also evaluated methanol fuel cells. Historical data on solar power systems installed on railcars indicated that solar power can be effectively used as a source of power. Testing of prototype devices for wind power generation indicated that wind power is not a viable option for a secondary source of power generation because of nominal train speeds in freight operations. Potential power sources were examined under different operational and environmental conditions to identify optimum configurations for deployment on an unattended rail vehicle.

Stage 5: Demonstration in Freight Service

The final stage of FRA's ATGMS development plan was a demonstration in normal freight service operation. ATGMS technology was demonstrated on a freight vehicle operating in typical revenue service to establish a vision for the use of this track assessment technology throughout the industry. FRA deployed its carbody-mounted ATGMS on a refurbished boxcar as part of a demonstration program conducted over 29 railroads, including 25 short line and regional railroads, between April 2016 and January 2017. Power systems specified during Stage 4 activities were installed on the boxcar to provide continuous power for the system. Data products from the surveys were provided to the surveyed railroads in several forms to meet the individual railroads' needs.

The overall timeline for the various development stages is illustrated in Figure 3.

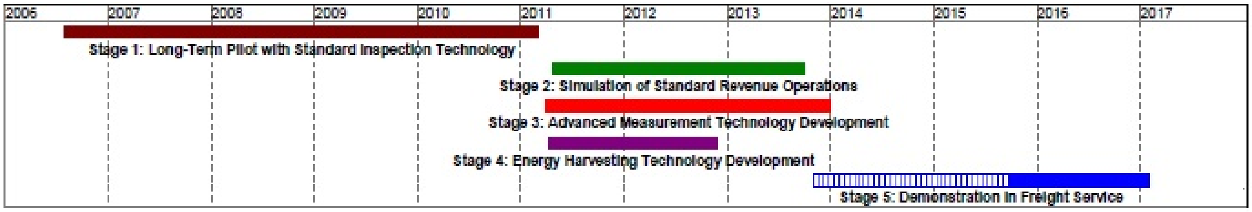


Figure 3: ATGMS Technology Development Timeline

3. ATGMS Technical Development

3.1 Measurement Approach and System Architecture

An operational schematic of FRA's ATGMS is illustrated in Figure 4. It consists of three major components, detailed below, that provides information needed for making decisions by railroad management and maintenance personnel:

1. **Data Collection Module** - This is installed and operated on a track-bound vehicle that transfers raw sensory data via a commercial cellular connection.

2. **Data Processing Server** – A server that receives and processes collected sensory data into actionable information stored in a searchable database.

3. **Web-Based Applications** – The applications include those dedicated to quality assurance and accessible reporting via a secure internet connection.

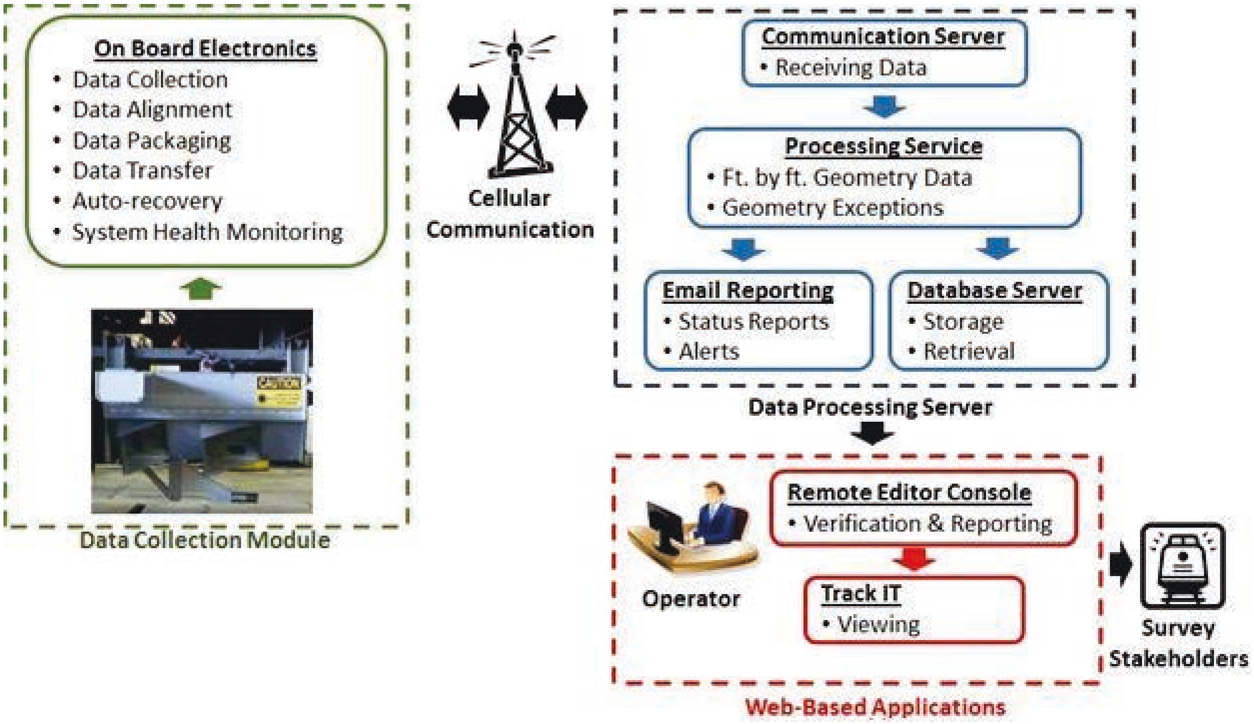


Figure 4: ATGMS System Architecture

The three major components of ATGMS architecture are comprised of several sub-modules, each performing specific functions as described in the sections below.

3.1.1 *Data Collection Module*

The data collection module consists of all equipment installed on the track-bound vehicle. This module has four major mechanical and electrical assemblies that together collect, package, and transfer foot-by-foot measurement data to ATGMS servers via a commercial cellular connection:

1. **Measurement Beam** – The mechanical structure that houses optical and inertial sensors. The beam is mounted either on the inboard truck frame above the primary suspension in the truck-mounted configuration, or to the carbody structure near one of the trucks in the carbody-mounted configuration. In both configurations, track geometry is measured approximately 34 inches from the center of the inboard axle.

2. **Onboard Electronics** – The electronic hardware installed in a rugged enclosure that can be mounted on the interior or exterior of the vehicle for full serviceability. The enclosure houses major components such as the signal processing unit, uninterruptable power supply (UPS) to protect against short-term power fluctuations, and communication hardware for transfer of data within the system, transmission of measurement data and system health status from the vehicle, as well as system set-up parameters and commands to the onboard system.

3. **GPS and Cellular Antennae** – This is mounted on the roof of the vehicle above the measurement beam to acquire location information as well as transmit and receive information.

4. **Tachometer** – The encoder mounted on the inboard axle closest to the measurement beam used to measure linear distance travelled along the track. The tachometer signal is used to trigger collection of foot-by-foot measurements and to synchronize data collected from different sensors.

3.1.2 *Data Processing Server*

Data collected on the vehicle is transferred to a data processing server via a commercial cellular connection. In addition to the foot-by-foot track measurement data, system diagnostic information is transmitted from ATGMS to the servers by status messages, which are hourly email notifications sent to the ATGMS operator/owner conveying the current status of onboard hard drive usage, processing load, and geographical location of the vehicle. Information is also transmitted from ATGMS to the servers using alert messages that are sent out when onboard electronics detect malfunctioning sensors or components.

When the ATGMS server receives a data packet, it performs a series of quality checks to ensure continuity of data and to acknowledge receipt of the data packet back to systems on the vehicle. The foot-by-foot geometry measurements are further analyzed to detect geometry exceptions outside established thresholds. Confirmed geometry exceptions, foot-by-foot geometry data, and location information are stored in the ATGMS database.

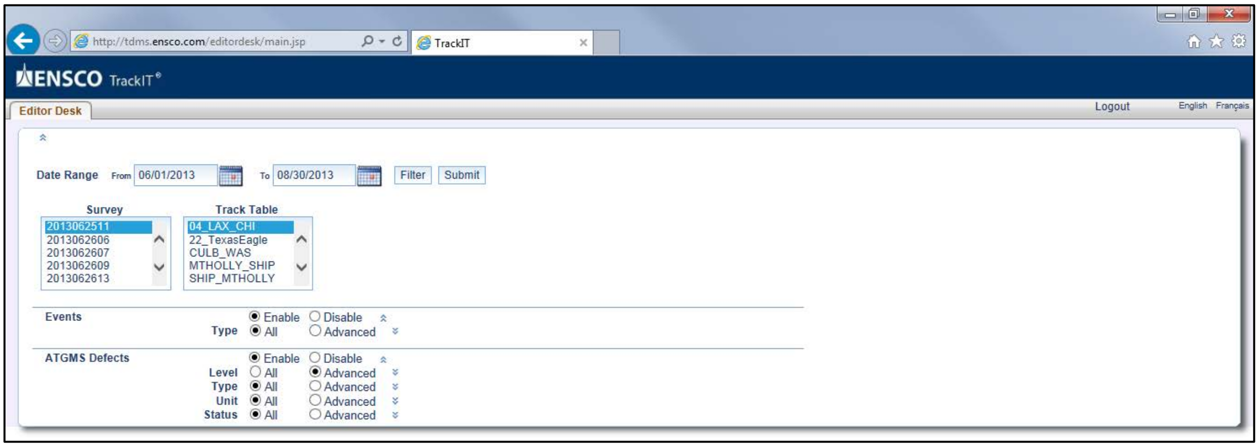
3.1.3 *Web-Based Applications*

ATGMS data information management and overall quality assurance is performed using two web-based applications, which are the Remote Editor Console and TrackIT®.

Remote Editor Console

The Remote Editor Console allows operators to review geometry exceptions detected by ATGMS in near real-time as part of FRA's data quality assurance process. Operators can use the secure web-based computer application to make any necessary adjustments to the survey information, including track class or track designation and exception edits, and distribute exception summary reports to authorized recipients. The Remote Editor Console also provides operators with the means to remotely identify/address any suspected data quality issues caused by system malfunctions.

Reviewers can select a specific survey or a range of surveys using dates or survey numbers and perform all aspects of survey data management through the user interfaces shown in Figure 5 and Figure 6.



Date Range From 06/01/2013 To 08/30/2013

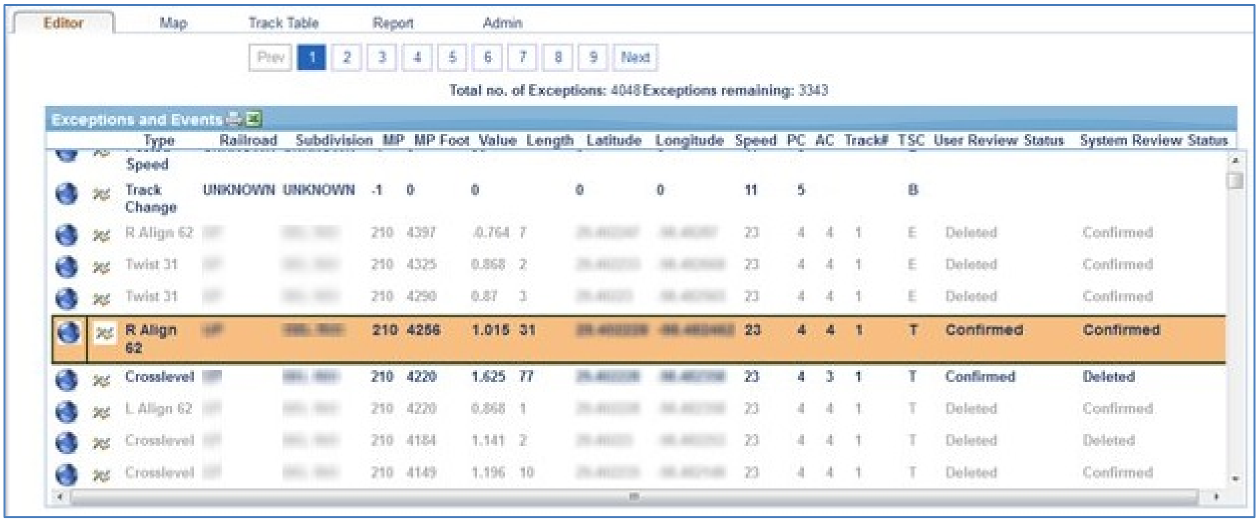
Survey
2013062511
2013062606
2013062607
2013062609
2013062613

Track Table
04_LAX_CHI
22_TexasEagle
CULB_WAS
MTHOLLY_SHIP
SHIP_MTHOLLY

Events ● Enable ○ Disable
Type ● All ○ Advanced

ATGMS Defects ● Enable ○ Disable
Level ○ All ● Advanced
Type ● All ○ Advanced
Unit ● All ○ Advanced
Status ● All ○ Advanced

Figure 5: Remote Editor Console Survey Data Selection Display



Total no. of Exceptions: 4048 Exceptions remaining: 3343

Type	Railroad	Subdivision	MP	MP Foot	Value	Length	Latitude	Longitude	Speed	PC	AC	Track#	TSC	User Review Status	System Review Status
Speed															
Track Change	UNKNOWN	UNKNOWN	-1	0	0		0	0	11	5			B		
R Align 62	[redacted]	[redacted]	210	4397	-0.764	7	[redacted]	[redacted]	23	4	4	1	E	Deleted	Confirmed
Twist 31	[redacted]	[redacted]	210	4325	0.868	2	[redacted]	[redacted]	23	4	4	1	E	Deleted	Confirmed
Twist 31	[redacted]	[redacted]	210	4290	0.87	3	[redacted]	[redacted]	23	4	4	1	E	Deleted	Confirmed
R Align 62	[redacted]	[redacted]	210	4256	1.015	31	[redacted]	[redacted]	23	4	4	1	T	Confirmed	Confirmed
Crosslevel	[redacted]	[redacted]	210	4220	1.625	77	[redacted]	[redacted]	23	4	3	1	T	Confirmed	Deleted
L Align 62	[redacted]	[redacted]	210	4220	0.868	1	[redacted]	[redacted]	23	4	4	1	T	Deleted	Confirmed
Crosslevel	[redacted]	[redacted]	210	4184	1.141	2	[redacted]	[redacted]	23	4	4	1	T	Deleted	Deleted
Crosslevel	[redacted]	[redacted]	210	4149	1.196	10	[redacted]	[redacted]	23	4	4	1	T	Deleted	Confirmed

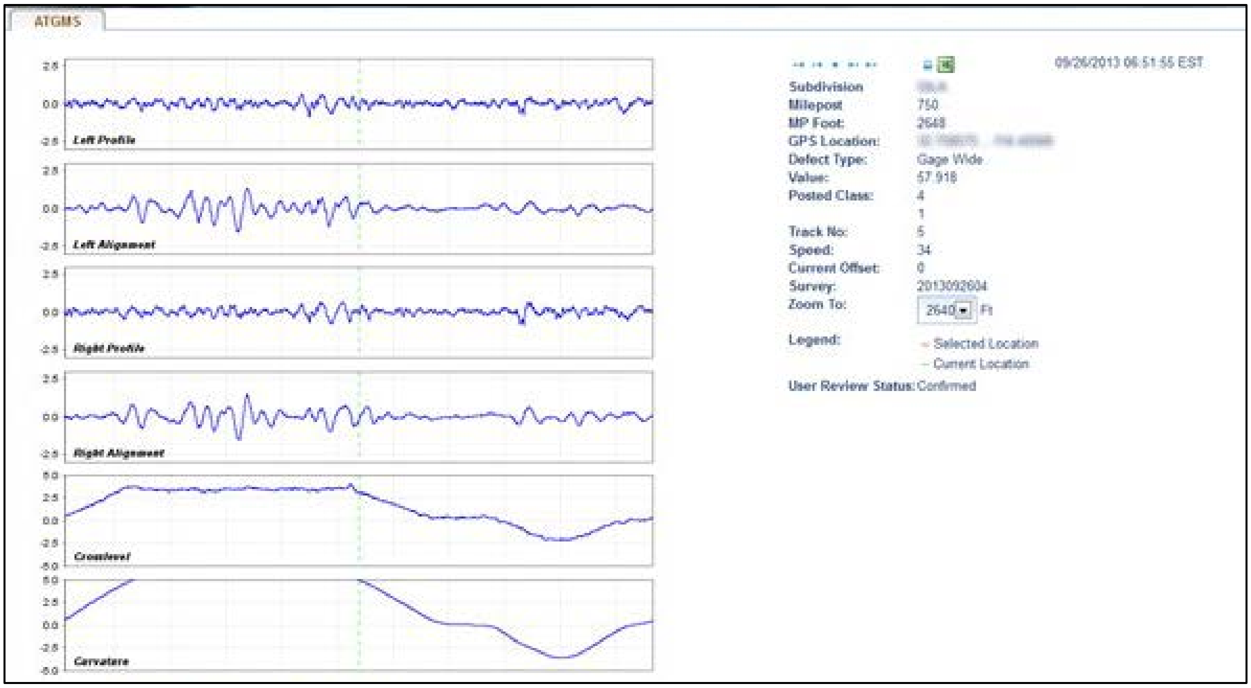
Figure 6: Remote Editor Console Survey Data Display

The user selects an event by clicking and highlighting the entry. Data selection allows the user to then view supporting information to analyze and validate the reported data. The available functions include:

- **Map** displays a Google™ Maps screen showing the location for the selected data for overall assessment and confirmation of individual track designation (see Figure 7).

Figure 7: Remote Editor Console Map View

- **Strip Chart** displays a separate window in which a foot-by-foot illustration of the selected survey data is provided (see Figure 8).

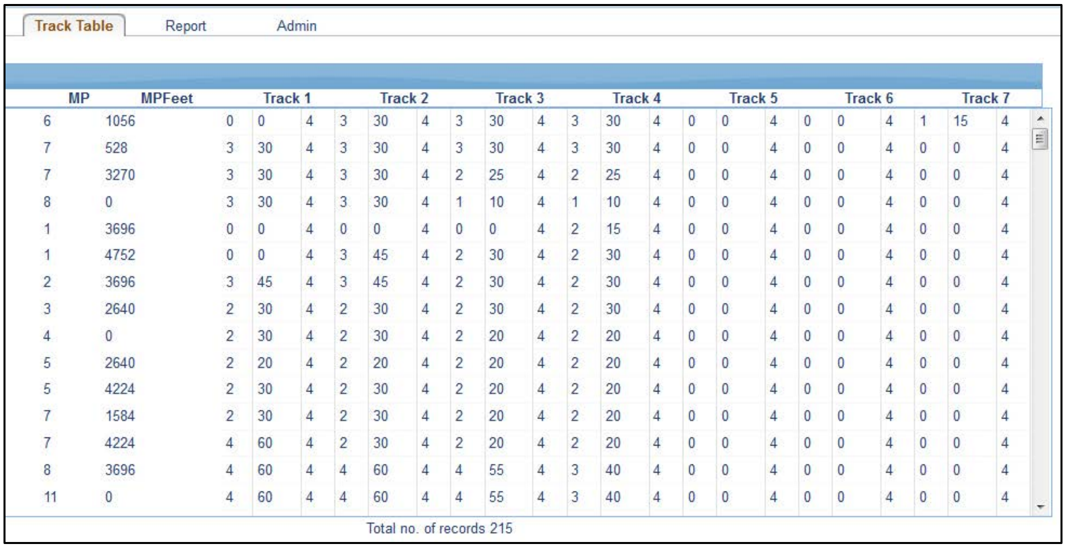


09/26/2013 06:51:55 EST

Subdivision [redacted]
Milepost 750
MP Foot: 2648
GPS Location: [redacted]
Defect Type: Gage Wide
Value: 57.918
Posted Class: 4
1
Track No: 5
Speed: 34
Current Offset: 0
Survey: 2013092604
Zoom To: 2640 Ft
Legend: Selected Location
Current Location
User Review Status: Confirmed

Figure 8: Remote Editor Console Strip Chart

- **Track Table** displays the available railroad-provided information regarding track class through the territory of interest (see Figure 9). A default track class is initially assigned to all survey results to initially identify potential track geometry exceptions; the default track class is configurable, but is typically established as Class 4. Reviewers select exceptions measured over portions of the survey and update the track class over that portion using information from the track table. The application will automatically generate or delete exceptions so that survey results correspond to the entered class. For example, if the reviewer determines that the surveyed class should be Class 3 between MPs 10 and 20 based on railroad provided information, then the reviewer can enter Class 3 for that MP range, and the system will delete all exceptions that were determined for higher classes. The reviewer is then left with Class 3 exceptions to be assessed.



MP	MPFeet	Track 1			Track 2			Track 3			Track 4			Track 5			Track 6			Track 7		
6	1056	0	0	4	3	30	4	3	30	4	3	30	4	0	0	4	0	0	4	1	15	4
7	528	3	30	4	3	30	4	3	30	4	3	30	4	0	0	4	0	0	4	0	0	4
7	3270	3	30	4	3	30	4	2	25	4	2	25	4	0	0	4	0	0	4	0	0	4
8	0	3	30	4	3	30	4	1	10	4	1	10	4	0	0	4	0	0	4	0	0	4
1	3696	0	0	4	0	0	4	0	0	4	2	15	4	0	0	4	0	0	4	0	0	4
1	4752	0	0	4	3	45	4	2	30	4	2	30	4	0	0	4	0	0	4	0	0	4
2	3696	3	45	4	3	45	4	2	30	4	2	30	4	0	0	4	0	0	4	0	0	4
3	2640	2	30	4	2	30	4	2	30	4	2	30	4	0	0	4	0	0	4	0	0	4
4	0	2	30	4	2	30	4	2	20	4	2	20	4	0	0	4	0	0	4	0	0	4
5	2640	2	20	4	2	20	4	2	20	4	2	20	4	0	0	4	0	0	4	0	0	4
5	4224	2	30	4	2	30	4	2	20	4	2	20	4	0	0	4	0	0	4	0	0	4
7	1584	2	30	4	2	30	4	2	20	4	2	20	4	0	0	4	0	0	4	0	0	4
7	4224	4	60	4	2	30	4	2	20	4	2	20	4	0	0	4	0	0	4	0	0	4
8	3696	4	60	4	4	60	4	4	55	4	3	40	4	0	0	4	0	0	4	0	0	4
11	0	4	60	4	4	60	4	4	55	4	3	40	4	0	0	4	0	0	4	0	0	4

Total no. of records 215

Figure 9: Remote Editor Console Track Table

- **Report** allows the user to configure, produce, and distribute survey reports. Two types of reports are provided to survey stakeholders from the Remote Editor Console. Non-Compliant Exception Reports (NCER) identifying track conditions that cannot support the current speed of the host train are immediately sent via email to FRA and railroad personnel. Track Assessment Reports (TAR) that summarize all events identified within a particular territory are distributed to FRA and railroad personnel at the end of each survey.

TrackIT®

Authorized end users such as railroad management, engineering, and maintenance-of-way personnel can view inspection results using TrackIT®, a secure web application for viewing information provided by multiple system deployments. Users can view geometry exceptions marked on aerial view maps, view strip charts showing sensor data, view data in tables, etc. Example displays are shown in Figure 10.

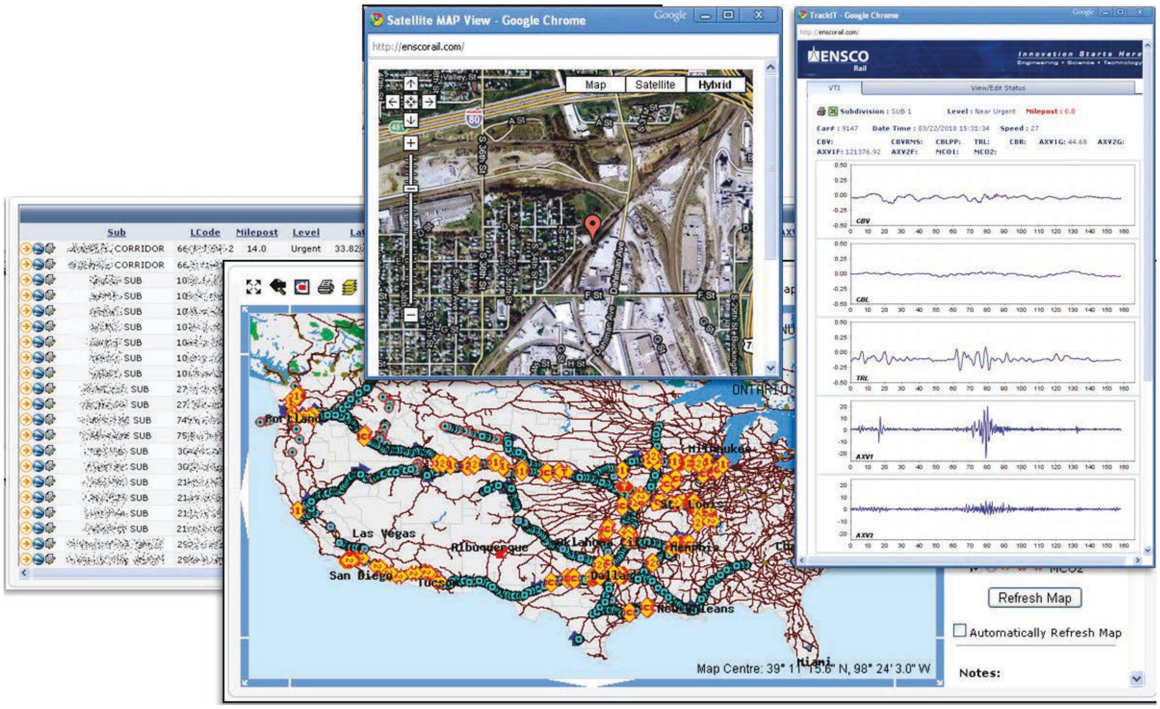


Figure 10: TrackIT® Data Viewing Displays

The sections below provide descriptions of the five main stages of ATGMS technology development including the goals, system development and configuration, testing, results, and lessons learned for each stage.

3.1.4 *Stage 1: Long-Term Pilot with Standard Inspection Technology*

ENSCO evaluated the early ATGMS proof of concept prototype on hi-rail vehicles as shown in Figure 11. Initial tests of the prototype system showed the potential for autonomous data collection, processing, detection, and reporting of geometry exceptions via a commercial cellular connection.

Figure 11: ATGMS Proof of Concept Testing on a High-Rail Vehicle

The first ATGMS proof of concept field test performed in March 2006 verified the overall system capabilities to properly collect and transmit track geometry data. Although successful in generating selected verifiable geometry results, this test highlighted the need for improving several technologies essential to autonomous performance and overall robustness of ATGMS including automatic determination of track class as well as self-identification and correction of sensor issues. Further field testing conducted in early May 2007 evaluated software remedies for detecting track class and vehicle direction of travel, dynamic sensor calibration based on long-term averages collected on tangent track, and corrected output of fiber optic gyroscopes based on filtered GPS data. Final field testing with the hi-rail vehicle in late May 2007 evaluated integration of a custom inertial measurement unit using standard sensors to address issues observed with the fiber optic gyroscopes and to verify software modifications improving track geometry calculations, including the determination of track class based on survey speed.

Tests on the hi-rail vehicle showed the viability of a fully equipped ATGMS employing cellular communication, and established the foundation for a long-term pilot program. The first pilot program, initiated in January 2008, focused on the evaluation of ATGMS on Amtrak Car 39000, a Superliner II sleeper car (Figure 12) in revenue service operation on Amtrak's Auto Train service between Lorton, VA, and Sanford, FL, over CSX track. The test bed on the Amtrak revenue vehicle fits the ideal operational scenario for initial use of the ATGMS repetitive operation of the test platform over a fixed route and availability of Head End Power (HEP) onboard the vehicle.

Figure 12: Stage 1 ATGMS Host Vehicle, Amtrak Car 39000

ATGMS operated on Amtrak Car 39000 from January 2008 to March 2011. During that time, ATGMS surveyed almost 460,000 miles of track, an average of approximately 153,000 miles per year. This extensive testing allowed identification of system deficiencies, facilitating design modifications that moved ATGMS toward increased robustness and reliability. Repetitively operating ATGMS on the 855-mile Lorton to Sanford route advanced testing procedures and established guidelines for subsequent ATGMS development stages. ENSCO analyzed track geometry data collected by ATGMS for consistency among the repeated runs and compared

ATGMS data to that collected by FRA's DOTX 220 manned track geometry inspection vehicle. In addition, CSX track inspectors field-verified a number of exceptions identified by ATGMS.

ATGMS operations on Amtrak Car 39000 also provided a rigorous testing ground for ATGMS hardware that contributed to advances in system reliability. Engineering changes made as a result of this testing included installation of a high precision GPS antenna, tachometer mounting improvements, and installation of laser/camera lens protection devices.

3.1.5 *Stage 1 Goals*

The main goal of the initial pilot study was to convert the ATGMS prototype into a field-deployable system using commercially available off-the-shelf equipment, and to evaluate the resulting system under revenue service operating conditions for an extended period of time. ATGMS technology development focused on the following:

- A ruggedized truck-mounted measurement beam and axle-mounted tachometer assembly with safety catch devices to contain components in case of catastrophic mechanical failure of the mounting structure. These measures were necessary because railroad personnel would not be inspecting autonomous data collection systems as often as they would inspect installations on manned inspection cars.
- A high-precision GPS receiver to accurately capture location information.
- A commercial cellular connection for transmitting track geometry exception data.
- Automated filtering algorithms for validation of geometry exceptions.
- An ATGMS server/database to receive and store detected geometry exceptions and corresponding foot-by-foot track geometry data. This data was to be available to authorized users via the initial deployment of the TrackIT® web application, providing capabilities to monitor survey data, create reports, and notify key personnel of serious track issues.

3.1.6 *Stage 1 System Configuration and Development*

ENSCO designed mounting hardware for the measurement beam in collaboration with Amtrak to ensure all fixtures were sufficiently robust to handle the dynamic load environment of the intended operation. To ensure installation and operation of ATGMS so that it would not jeopardize Amtrak passenger operations, safety catch devices were installed to contain the measurement beam in case of failure of the mounting structures.

The measurement beam was mounted to the A-End truck. Mechanical mounting fixtures were designed to withstand 25g vertical and 15g lateral shocks over fatigue life cycles consistent with Amtrak requirements. It should be noted, however, that the final design of the truck-mounted beam required removal of the measurement beam and mounting brackets from the truck frame in advance of any wheel or axle maintenance activities—an issue that would negatively impact the long-term viability of this design approach. Final installations of the externally mounted equipment are shown in Figure 13 and Figure 14.

Figure 13: Stage 1 ATGMS Measurement Beam on Amtrak Car 39000

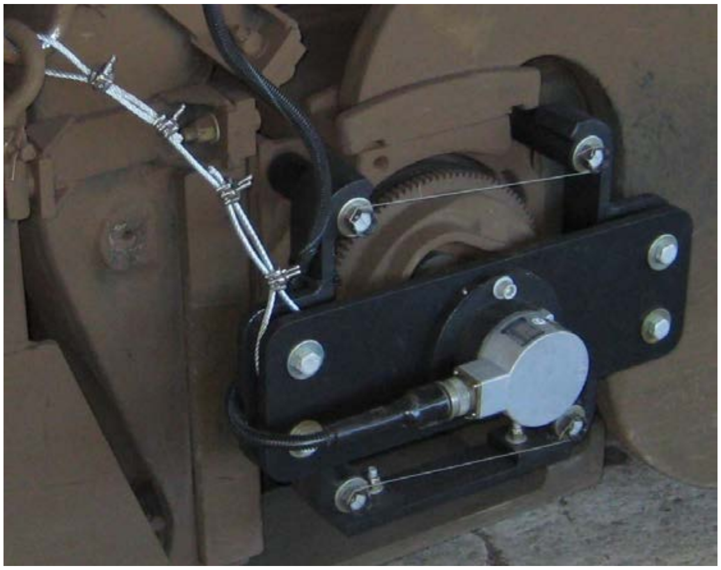


Figure 14: Stage 1 ATGMS Tachometer Assembly on Amtrak Car 39000

GPS location and linear distance measurement subsystems were updated to accurately mark track geometry measurements with location information. Signal processing and communication hardware were housed in enclosures that were temporarily installed in an equipment locker (Figure 15). HEP was used to power ATGMS.

Figure 15: Stage 1 ATGMS Electronics on Amtrak Car 39000

During Stage 1, the ATGMS processed geometry data on the vehicle and transferred exceptions to ENSCO's TrackIT® application in near real-time. ENSCO recognized early in ATGMS development that a large number of false alarms would be detrimental to the success of the system; therefore, ENSCO's development focused on creating and refining automatic data filtering on the TrackIT® platform. The ATGMS data flow employed during the initial stage of development is shown in Figure 16.

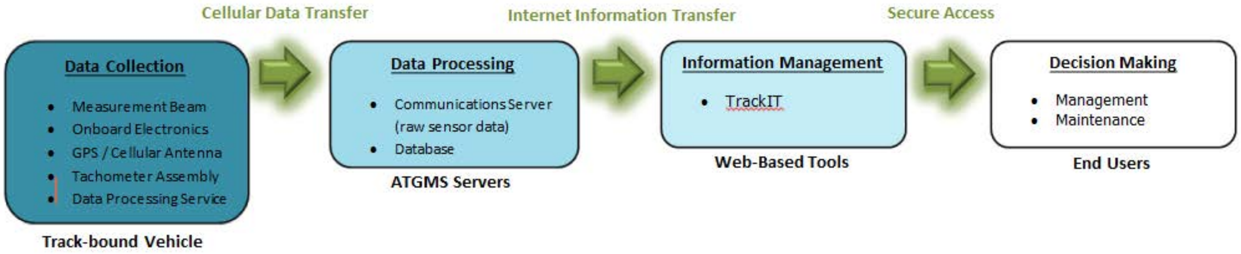


Figure 16: ATGMS Data Flow Employed in Stage 1 Development

Repeatable data was a critical aspect of the implementation of the pilot program with CSX. For the ATGMS test scenario, potential track defects identified for follow-up field inspection by CSX would have to be repeated over several consecutive surveys before CSX would deploy field personnel for remedial action. If repeated defects were found, a summary report of the location of interest was provided to the railroad for investigation. Defects that were believed to be an imminent threat for derailment were brought to the railroad's attention immediately. The first case of a confirmed exception employing this approach occurred in 2008. A narrow gage condition was detected during multiple northbound and southbound ATGMS surveys conducted in September and October; this event is shown in Figure 17. CSX was informed of the measurements, and it dispatched maintenance personnel to the location. They verified the narrow gage measurement.

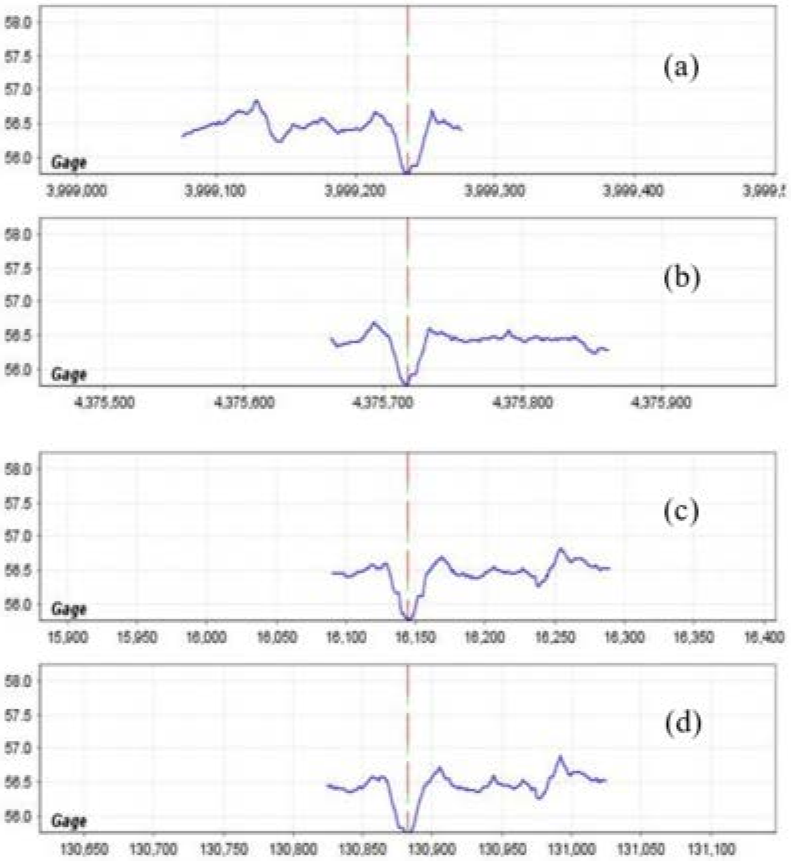


Figure 17: Repeated Narrow Gage Measurements Collected with ATGMS

(Narrow Gage Measurements - (a) 55.76, (b) 55.76, (c) 55.77, and (d) 55.74 inches)

During the first several months of operation on Amtrak Car 39000, ATGMS suffered multiple tachometer failures due to cracks in the tachometer mounting. The design of the mounting bracket was changed (Figure 18) in April 2008 and system inspection procedures were modified to monitor the tachometer condition. There were no further cracking issues observed during the remaining Stage 1 efforts.

Figure 18: Tachometer Modification

In late 2008 and early 2009, Amtrak Car 39000 was out of service for 11 weeks for a scheduled overhaul. A comprehensive weld inspection was conducted on ATGMS components and no major issues were found. During this time ATGMS underwent numerous upgrades, including:

- Software update to improve geometry processing and improved communication robustness
- Implementation of automatic exception processing algorithms
- Improved vertical accelerometer mounts to reduce chance of sensor saturation
- Replacement of tachometer coupler used to connect the unit to the axle and establishment of new inspection procedures
- Multiple Web site updates to improve the review and editing of exception data.

In April 2009, an Automatic Location Detector (ALD) sensor was added to ATGMS to detect switches. At approximately the same time, a Laser Protection System (LPS) was added to ATGMS to keep optical lenses clean over extended periods of time. An electro-mechanical device advanced clear film that covered the lenses based on a software-controlled timer to remove dust and dirt deposited in front of the optical sensors. Although the LPS provided protection for ATGMS optics, frequent malfunctions due to flying debris and issues with the film resulted in degraded or lost survey data from time to time. The LPS continued to be reevaluated and refined during Stage 1 and subsequent development efforts. Aside from LPS issues, the optical sensors worked well.

In November 2009, a high-resolution GPS antenna was installed and tested. While the resolution provided by the GPS was sufficient to distinguish which track the vehicle was on, applying an actual track number and track class to the survey data would require detailed information from the railroads to be cross-referenced to specific GPS coordinates in a look-up table. This testing revealed that with the proper reference information provide by a railroad, the autonomous system would be able to reliably identify track number and other important geo-referenced railroad information in multi-track locations.

3.1.7 *Stage 1 Testing*

ATGMS testing evolved throughout Stage 1. The baseline testing concept involved three methods for evaluating ATGMS survey data:

1. Comparison of ATGMS-collected data to data collected by the manned DOTX 220 track survey vehicle.

2. Comparison of multiple ATGMS-collected data sets over the same track.

3. Field validation of ATGMS-determined exceptions by CSX maintenance personnel.

ENSCO assessed foot-by-foot geometry data stored locally on ATGMS for diagnostic purposes by comparing it to data collected by the DOTX 220 manned survey vehicle on selected test zones traversed in February and October 2008 over the Auto Train route.

Statistics summarizing the differences between ATGMS measurements and track geometry measured by DOTX 220 in February 2008 are shown in Table 1. The results show that the differences between data captured from the manned and unmanned geometry measurement systems were within acceptable repeatability limits except for the average difference between gage and crosslevel. These differences were attributed to small initial differences between the two vehicles.

Table 1: ATGMS to DOTX 220 Data Comparison Results, February 2008

	Curvature (degrees/100 ft)		Crosslevel (inches)		Gage (inches)	
	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation
Difference	**0.0028**	**0.0580**	0.1836	0.1157	0.0372	**0.0372**
Threshold	*0.01*	*0.15*	*0.03125*	*0.0625*	*0.03125*	*0.0625*

	Alignment 31' MCO (inches)				Alignment 62' MCO (inches)			
	Left		Right		Left		Right	
	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation
Difference	**0.0001**	**0.0293**	**0.0001**	**0.0310**	**0.0001**	**0.0380**	**0.0000**	**0.0388**
Threshold	*0.03125*	*0.125*	*0.03125*	*0.125*	*0.03125*	*0.125*	*0.03125*	*0.125*

Profile 31' MCO (inches)		Profile 62' MCO (inches)	
Left	Right	Left	Right

	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation
Difference	0.0000	0.0442	0.0000	0.0484	0.0001	0.0489	0.0001	0.0539
Threshold	*0.03125*	*0.0625*	*0.03125*	*0.0625*	*0.03125*	*0.0625*	*0.03125*	*0.0625*

(values exceeding targeted thresholds indicated with red/underline)

A strip chart overlay comparison of the data collected by ATGMS and the manned DOTX 220 in February 2008 is shown in Figure 19.

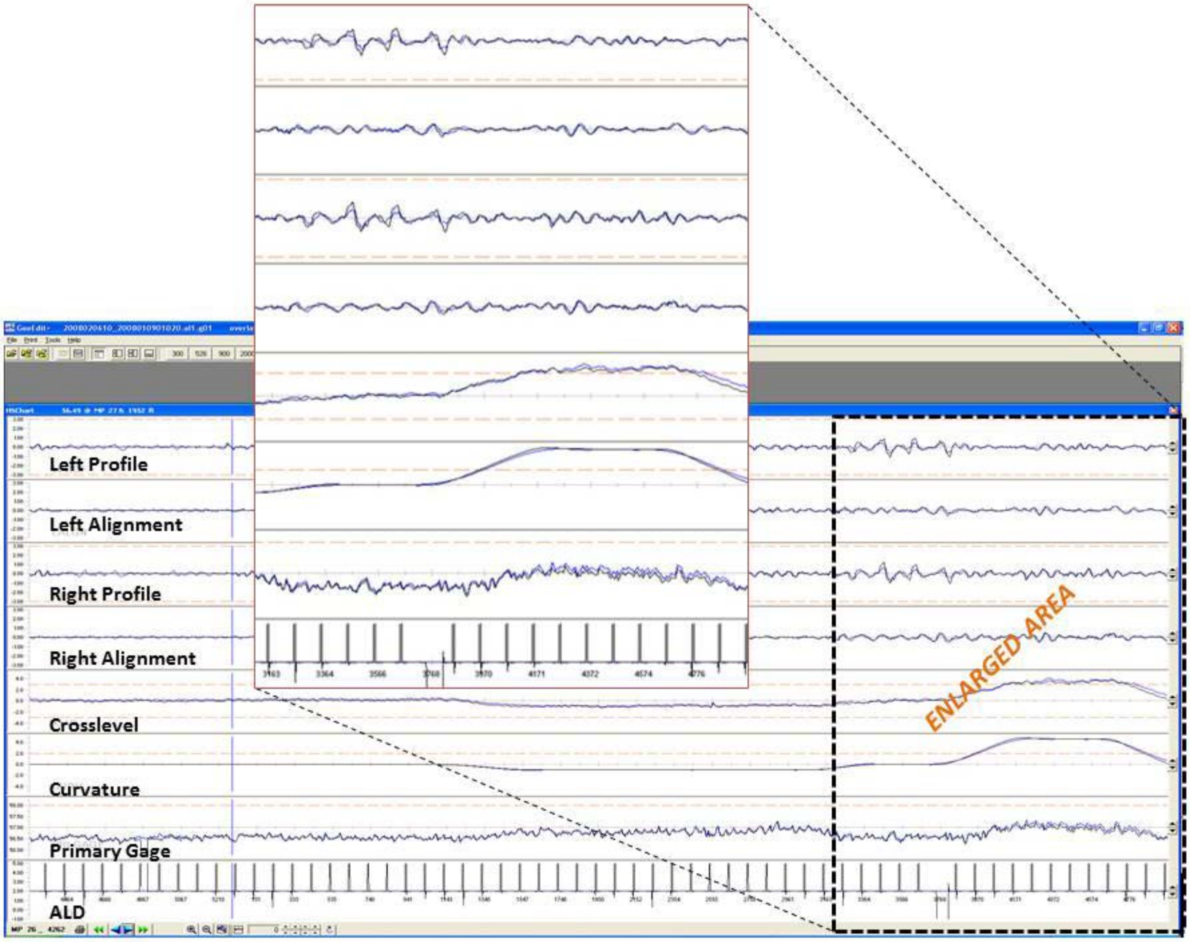


Figure 19: Track Geometry Data Overlay of ATGMS and DOTX 220, February 2008

Analysis of this early data revealed discrepancies in speed-sensitive data which was determined to be caused by a flawed tachometer calibration value. The tachomoter was re-calibrated, and the ATGMS software was adjusted to prevent oversampling of data at high speeds. Small differences in gage measurements were addressed through adjustments to gage system calibrations on ATGMS.

The repeatability of ATGMS measurements, particularly over time, was critical. Table 2 shows the repeatability of ATGMS measurements collected over an assessment zone measuring 7,000 feet in length during surveys conducted in February 2008 and July 2008. Comparisons of ATGMS measurements taken 5 months later indicates good agreement.

Table 2: Comparison of ATGMS Measurements over 7000-foot Evaluation Zone, February 2008 and July 2008

	Curvature (degrees/100 ft)		Crosslevel (inches)		Gage (inches)	
	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation
Difference	**-0.0048**	**0.0244**	**-0.0221**	**0.0617**	**-0.0092**	**0.0620**
Threshold	*0.01*	*0.15*	*0.03125*	*0.0625*	*0.03125*	*0.0625*

	Alignment 31’ MCO (inches)				Alignment 62’ MCO (inches)			
	Left		Right		Left		Right	
	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation	Mean Diff.	Std. Deviation
Difference	**-0.0001**	**0.0332**	**0.0001**	**0.0301**	**0.0001**	**0.0385**	**0.0002**	**0.0380**
Threshold	*0.03125*	*0.125*	*0.03125*	*0.125*	*0.03125*	*0.125*	*0.03125*	*0.125*

	Profile 31’ MCO (inches)				Profile 62’ MCO (inches)				Profile 124’ MCO (inches)			
	Left		Right		Left		Right		Left		Right	
	Mean Diff.	Std. Dev.	Mean Diff.	Std. Dev.	Mean Diff.	Std. Dev.	Mean Diff.	Std. Dev.	Mean Diff.	Std. Dev.	Mean Diff.	Std. Dev.
Difference	0.0000	0.0345	0.0000	0.0338	-0.0001	0.0380	0.0001	0.0374	-0.0002	0.0432	0.0001	0.0406
Threshold	*0.03125*	*0.0625*	*0.03125*	*0.0625*	*0.03125*	*0.0625*	*0.03125*	*0.0625*	*0.03125*	*0.0625*	*0.03125*	*0.0625*

The remaining Stage 1 activities focused on general system improvements including the processing of track geometry exceptions, particularly with respect to filtering of false exceptions. Results of these efforts are discussed in Section 4.1.

3.1.8 *Conclusions and Lessons Learned*

Stage 1 efforts between January 2008 and March 2011 validated the feasibility of ATGMS. The deployed system achieved overall objectives and provided a test bed for improving the baseline hardware design, accumulating test data, testing software exception filtering algorithms, and refining test procedures for succeeding ATGMS development stages.

The major results of Stage 1 ATGMS development were highlighted by the following:

- ATGMS produced repeatable data over time, a key aspect to the reliability of the system and its data products.
- The system was generally reliable.
- Automatic data filtering was effective in removing instances in which certain conditions in the data yielded false exceptions, but improvements were warranted.

The following plans were established to address several issues in subsequent stages of development:

- Improvements to the truck-mounted measurement beam approach to minimize interference with truck and wheel set maintenance, and to reduce the need for custom-made support structures that significantly depend on truck type and vehicle loading environment.
- Enhancements to methods employed with the LPS to keep optical windows clear of dirt and debris.
- Increased health monitoring and automatic recovery features within the system to increase overall robustness and provide a more comprehensive look at system health and data quality than was done with the prototype system.

3.2 Stage 2: Simulation of Standard Revenue Operations

Stage 2 tested the ATGMS under long distance, revenue service operating conditions. ENSCO removed FRA's ATGMS from the Amtrak Superliner II and installed it on DOTX 221 (Figure 20, following inspection and refurbishment of the system. DOTX 221 is a sleeper-lounge car operated by FRA as a crew car during cross-country surveys on passenger train routes.

The system was altered to provide delivery of all raw sensor data, not just exception data, to the ATGMS server via a commercial cellular link. Collection and transmission of foot-by-foot data allows evaluation of overall track conditions, thus enabling users to identify track issues before safety thresholds are reached.

DOTX 221 operated in consist with FRA's DOTX 220 manned inspection vehicle (Figure 21) during ATIP surveys conducted over Amtrak passenger routes between fall 2011 and spring 2013. Tandem operation provided the opportunity to perform direct comparisons of foot-by-foot measurement and exception data collected with both systems. The operating scenario also enabled the DOTX 220 crew to conduct regular inspections of ATGMS and address any minor issues during cross-country operations.

Figure 20: Stage 2 ATGMS Host Vehicle—DOTX 221

Figure 21: ATIP Manned Geometry Inspection Vehicle—DOTX 220

3.2.1 *Stage 2 Goals*

The goals for Stage 2 development efforts include:

- Increase autonomy with near real time transmission of all ATGMS-acquired foot-by-foot sensor data via cellular transmission to the ATGMS server.
- Automatic transfer of additional system health status data and GPS location on a regular basis, providing information to augment monitoring, maintenance, operational, and technical troubleshooting efforts.
- Improved robustness through remote restart of the system.
- Automated email notifications automatically sent to specified stakeholders to inform them of ATGMS-identified exceptions, system alerts, and status.
- Validate data quality comparison of track geometry collection and analysis processes employed by autonomous and manned operations to establish and refine overall performance.
- Improved ATGMS installation to facilitate long-term deployment with minimal maintenance.

3.2.2 *Stage 2 System Configuration and Development*

ENSCO designed a new truck mount for ATGMS to accommodate structural differences between the Amtrak Car 39000 and DOTX 221. The modified measurement beam and structural modifications are shown in Figure 22.

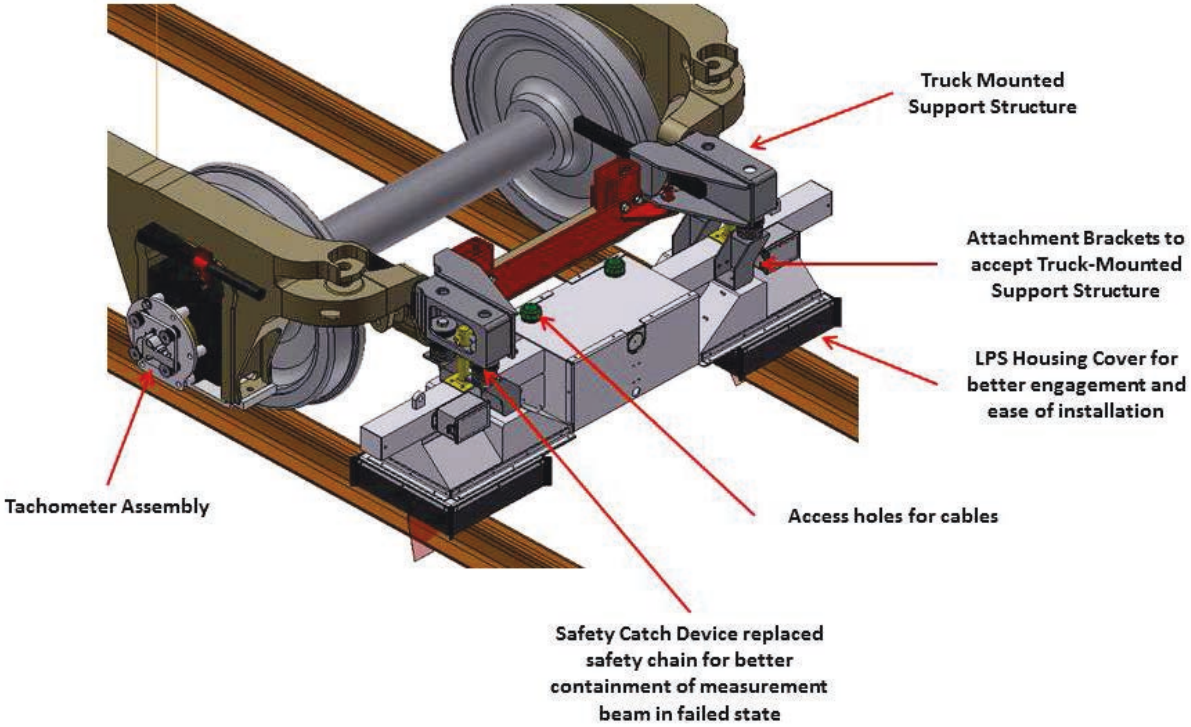


Figure 22: Stage 2 ATGMS Structural Modifications

Figure 23 is a schematic of the ATGMS configuration on DOTX 221 and Figure 24 shows the final installation of ATGMS on DOTX 221. The ATGMS was commissioned by undergoing repeatability testing on Norfolk Southern Corporation’s Lurgan Branch between Shippensburg, PA, and Mount Holly Springs, PA.

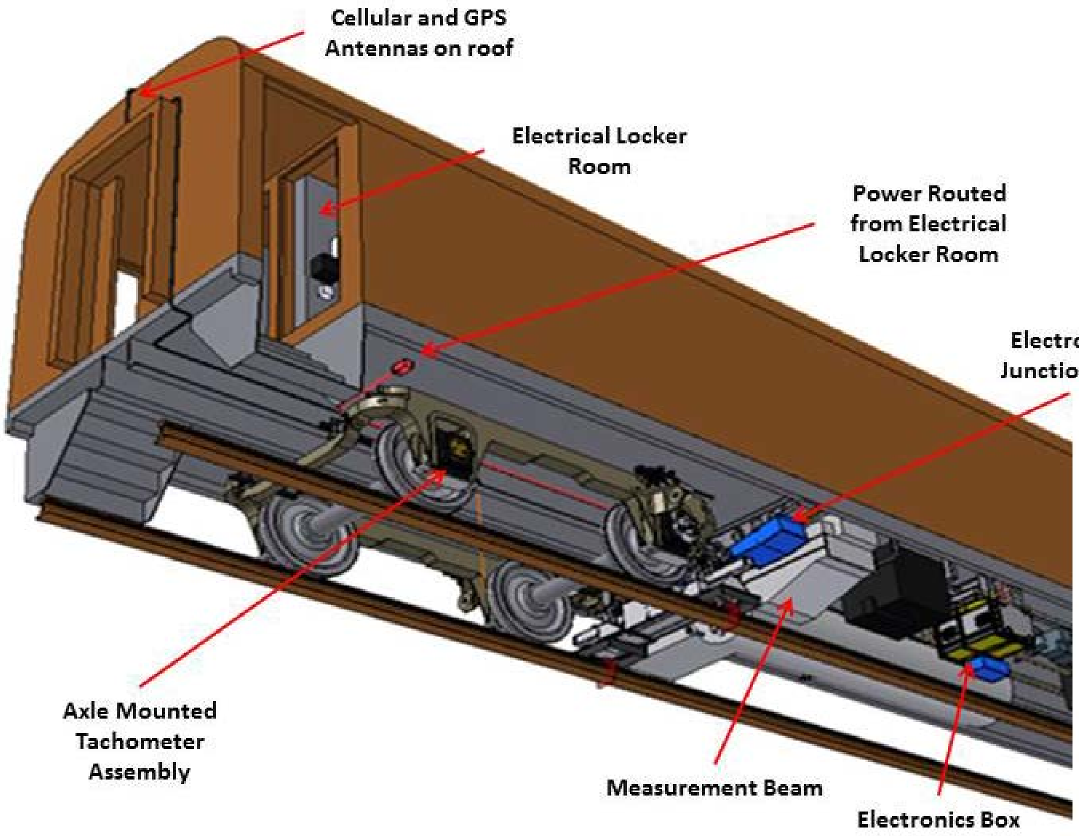


Figure 23: ATGMS Configuration on DOTX 221

Figure 24: ATGMS Installation on DOTX 221

For the DOTX 221 installation, ENSCO mounted ATGMS electronics on the exterior of the vehicle. A ruggedized, weather-sealed enclosure was selected to house the Signal Conditioning Unit (SCU), an Uninterruptable Power Supply (UPS), and a communications network switch.

The electronics enclosure support structure (Figure 25) was designed to withstand vehicle acceleration forces and allow mounting near the vehicle brake rack.

Figure 25: ATGMS Electronics Box on DOTX 221

Power to the electronics box was supplied by a transformer installed in the electrical cabinet to convert train-line 480VAC to 120VAC and an automatic power transfer switch installed to automatically switch ATGMS power to DOTX 221's backup generator when train-line power was not available.

At the start of Stage 2, ENSCO developed a new ATGMS data process. Raw, foot-by-foot sensor data was packaged, queued, and transmitted to ATGMS servers for processing, analysis, and storage in 528 foot packets, each containing a unique packet identifier. At the server, the packages were arranged by identifier and data processed for insertion into a database. To ensure all data packets were successfully transferred to ATGMS servers, an acknowledgement message was sent back to a data collection module on the vehicle upon receipt of each data packet.

As in Stage 1, an automated algorithm using specific pre-defined thresholds and signal processing methods was used to detect and verify validity of detected geometry exceptions. In addition, a web-based Remote Editor Console application (see Section 3.1.3) was developed to enhance ATGMS information management and quality assurance. The final architecture of ATGMS resulting from efforts conducted during Stage 2 is shown in Figure 26.

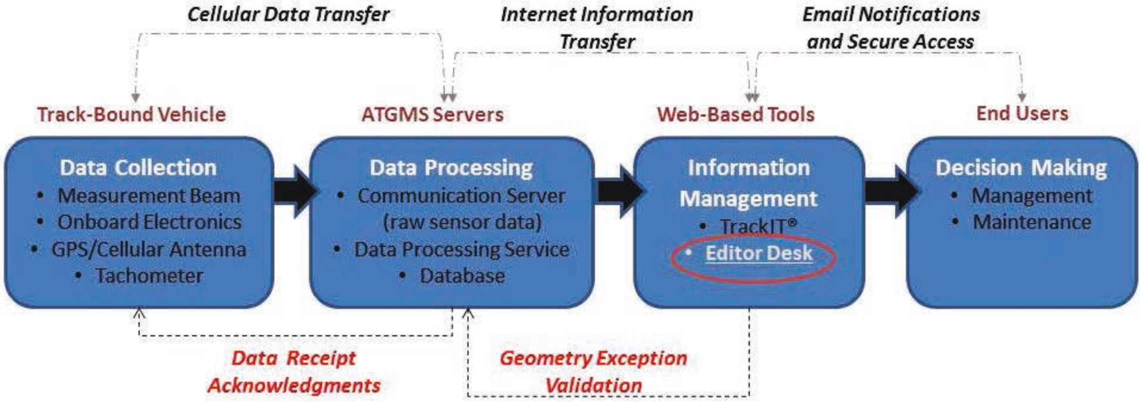


Figure 26: Stage 2 ATGMS Final Architecture

3.2.3 *Stage 2 Testing*

ATGMS on DOTX 221 was operated in consist with FRA's DOTX 220 as part of FRA's ATIP Amtrak assessment surveys between August 21 and November 4, 2011, during which time the system collected more than 4,300 miles of foot-by-foot geometry data. The 2011 run was used to identify and remediate issues related to hardware and onboard electronics, data transfer and overall quality as well as the automated detection and reporting of geometry exceptions. Analysis of the 2011 survey identified several hardware and software issues of varying degrees of criticality that were addressed in advance of 2012 operations.

DOTX 221 was operated in consist with DOTX 220 during Amtrak assessment surveys conducted between March and June 2012 over approximately 19,000 track miles; details of the survey are provided in Table 3.

Table 3: March 2012 Amtrak Assessment Survey

Origin	Destination	Survey Miles	Start Date	End Date
Washington, DC	New Orleans, LA	1,155	03/29/2012	03/30/2012
New Orleans, LA	Los Angeles, CA	1,939	04/02/2012	04/04/2012
Los Angeles, CA	Oakland, CA	468	04/06/2012	04/06/2012
Oakland, CA	Los Angeles, CA	468	04/06/2012	04/06/2012
Los Angeles, CA	Chicago, IL	2,222	04/09/2012	04/11/2012
Chicago, IL	New Orleans, LA	918	04/23/2012	04/24/2012
New Orleans, LA	San Antonio, TX	575	04/25/2012	04/25/2012
San Antonio, TX	Chicago, IL	1,305	04/30/2012	05/01/2012
Chicago, IL	Washington, DC	919	05/03/2012	05/04/2012
Washington, DC	Miami, FL	1,288	05/07/2012	05/08/2012
Miami, FL	Washington, DC	930	05/10/2012	05/10/2012
Washington, DC	Chicago, IL	777	05/21/2012	05/22/2012
Chicago, IL	Oakland, CA	1,791	05/23/2012	05/24/2012
Oakland, CA	Seattle, WA	916	06/01/2012	06/01/2012
Seattle, WA	Chicago, IL	2,203	06/04/2012	06/06/2012
Chicago, IL	Boston, MA	1,020	06/07/2012	06/07/2012

The performance of ATGMS was characterized by:

- Exceptions to the track geometry limits specified in the FRA Track Safety Standards detected by each system. Geometry exceptions reported by FRA's manned geometry inspection system on DOTX 220 were considered as "ground truth" for this analysis.
- Foot-by-foot track geometry data collected by the unmanned and manned systems over more than 314,000 non-consecutive feet of the survey. Areas for comparison were selected based on locations with track geometry exceptions as reported by the manned system onboard DOTX 220. Differences in gage, profile, alignment, crosslevel, and curvature measurements collected by the two systems were compared to established thresholds used by FRA to assess overall agreement between multiple measurement systems.

The analyses are detailed in ENSCO Document SERV-REPT-0000507, provided in Appendix A. For each portion of the overall survey, ENSCO considered numerous foot-by-foot geometry comparisons such as that illustrated in Figure 27. For each geometry parameter considered, the mean and maximum difference between measurements as well as the standard deviation between the measurements from the two systems were determined. The results were used to determine overall ATGMS performance.

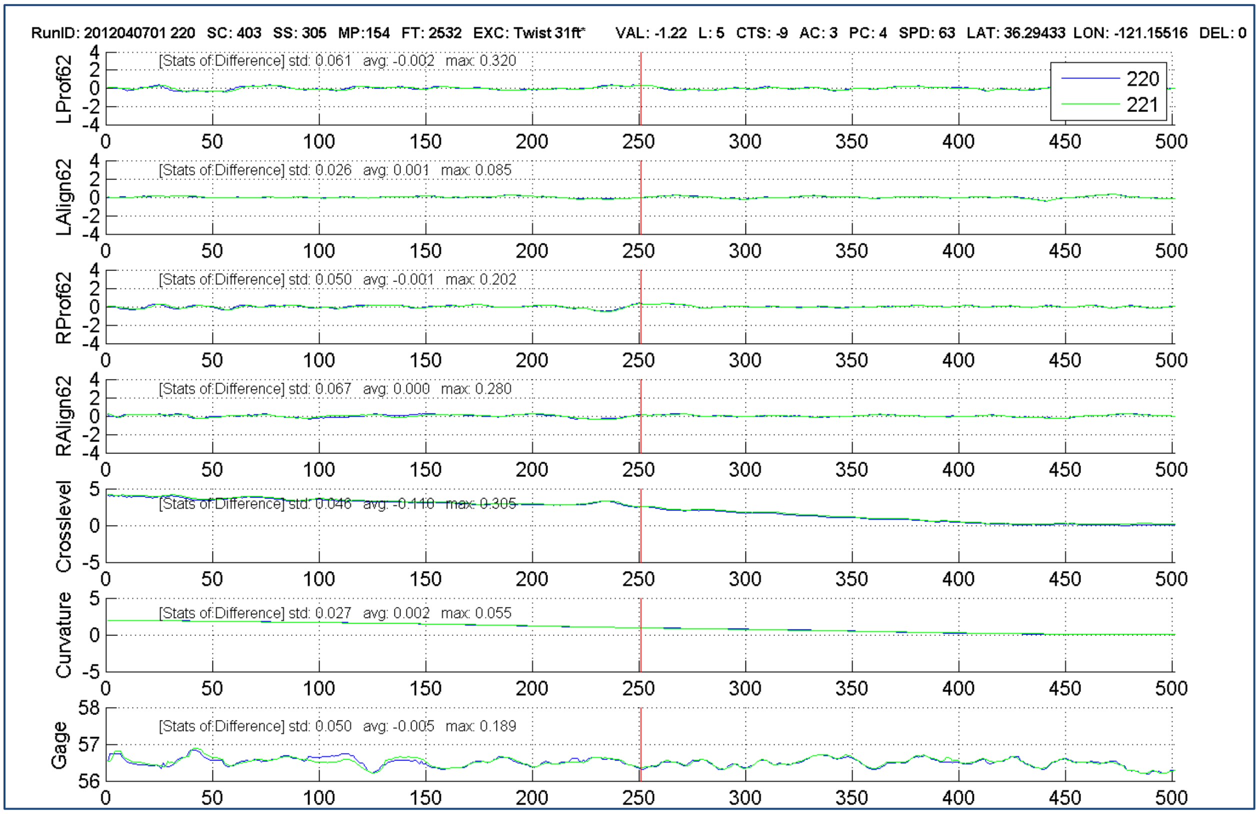


Figure 27: Comparison of Data Collected with DOTX 220 and ATGMS Between Oakland and Los Angeles—April 7, 2012

Summary statistics from over 351,000 feet of track are shown in Table 4. Despite crosslevel and curvature measurement differences being slightly higher than acceptable (which resulted in adjustment of calibration settings on the ATGMS), the analysis showed that that the quality of data collected by ATGMS on DOTX 221 was comparable to that collected by the manned track geometry system onboard DOTX 220.

Table 4: Statistics of ATGMS and ATIP Foot-by-Foot Track Geometry Data, March 2012 Amtrak Assessment Survey

Geometry Parameter	Mean Difference	Standard Deviation
Profile (Inches)	-0.005	0.083
Alignment (Inches)	0.000	0.055
Crosslevel (Inches)	-0.078	0.110
Curvature (Deg.)	0.017	0.031
Gage (Inches)	-0.011	0.031

(Results outside expected acceptable limits are shown in red/underline font)

Not all ATGMS-generated exceptions matched the 1,193 reported exceptions from the DOTX 220 manned track geometry inspection vehicle. Each of the mismatched exceptions was attributed to one of seven cause categories with the most critical factors affecting ATGMS performance being associated with:

- ATGMS speed-based class of track determination logic. Manned ATIP systems employ the actual class of track from track tables and slow order information provided by the railroad. At this stage of development, ATGMS used the measured vehicle speed. Therefore, if the vehicle speed was lower than the posted class due for any reason, the class of track used by ATGMS would be lower than what would have been employed by ATIP resulting in ATGMS not detecting geometry exceptions.
- Small differences in geometry measurements from the two systems resulting from the systems being on two different vehicles.
- Logic used with ATGMS failing to remove potential defects that were caused by track features that traditionally create issues for automated measurement systems, such as switches, or occasional data issues resulting from direct sunlight on the optical sensors. These events are typically removed from the survey results by experienced survey crews.
- Erroneous deletion and/or validation of exceptions in the automated exception processing.

Following assessment of the performance of ATGMS during the 2012 Amtrak Assessment Survey, ENSCO and FRA commenced with the development of the Remote Editor Console, described in Section 3.1.3, to augment ATGMS track class determination logic and automated exception editing.

The use of ATGMS in conjunction with Remote Editor Console was initially evaluated during surveys conducted with DOTX 221 in Amtrak revenue service operations on Washington, DC - Miami, FL, and Washington, DC - Chicago, IL, surveys conducted between December 2012 and April 2013. Following these tests, FRA conducted a complete evaluation of DOTX 221 ATGMS operations during the 2013 ATIP Amtrak Assessment Survey when DOTX 221 was not connected to the manned DOTX 220 inspection vehicle. Details of the assessment are presented in ENSCO Document SERV-REPT-0000578, provided in Appendix B.

The 2013 ATIP Amtrak Assessment consisted of 17 one-way trips starting in Washington, DC, on July 29, 2013, and ending in Washington, DC, on September 29, 2013, covering more than 19,000 miles of track as listed in Table 5.

Table 5: July 2013 ATIP Amtrak Assessment Survey

Origin	Destination	Route Miles	Start Date	End Date
Washington, DC	Miami, FL	1,235	7/29/2013	7/30/2013
Miami, FL	Washington, DC	1,164	8/1/2013	8/2/2013
Washington, DC	New Orleans, LA	1,152	8/12/2013	8/13/2013
New Orleans, LA	Chicago, IL	934	8/14/2013	8/15/2013
Chicago, IL	Emeryville, CA	2,438	8/19/2013	8/21/2013
Oakland, CA	Seattle, WA	913	8/27/2013	8/28/2013
Seattle, WA	Chicago, IL	2,205	8/29/2013	8/30/2013
Chicago, IL	Washington, DC	922	9/3/2013	9/4/2013
Washington, DC	Chicago, IL	780	9/6/2013	9/7/2013
Chicago, IL	San Antonio, TX	1,305	9/9/2013	9/10/2013
San Antonio, TX	New Orleans, LA	573	9/13/2013	9/13/2013
New Orleans, LA	Chicago, IL	934	9/16/2013	9/17/2013
Chicago, IL	Los Angeles, CA	2,265	9/18/2013	9/20/2013
Los Angeles, CA	Oakland, CA	464	9/23/2013	9/23/2013
Oakland, CA	Los Angeles, CA	464	9/24/2013	9/24/2013
Los Angeles, CA	Chicago, IL	2,728	9/25/2013	9/28/2013
Chicago, IL	Washington, DC	780	9/29/2013	9/29/2013

As exception data became available in the ATGMS database, an operator used the web-based Remote Editor Console to correct for actual track class as well as individual track number and to validate individual exceptions and overall track measurement quality by considering foot-by-foot geometry data, system health information, and other system data. Confirmed exceptions were sent to FRA personnel and railroad representatives.

As part of the data evaluation process throughout the 2013 Amtrak Assessment Survey, foot-by-foot geometry data collected over selected track segments on multiple days were compared to assess overall data stability. This evaluation data included two sets of geometry data collected on the same track between Los Angeles, CA, and Oakland, CA, on consecutive days; two sets of geometry data collected 40 days apart on the same track between Memphis, TN, and New Orleans, LA; and two sets of geometry data collected 19 days apart on the same track between Tempe, TX, and San Antonio, TX. Details of this analysis are provided in Appendix B. Statistics of differences between the sets of geometry data on the cited track segments showed that data collected with ATGMS were relatively consistent given changes that can be expected in the track over the periods of time considered. Table 6, taken from Appendix B, illustrates the repeatability of the ATGMS measurements over the same track over consecutive days; the only parameter outside the expected values was the difference in crosslevel, which necessitated additional adjustments to calibration parameters.

Table 6: Statistics of Difference between Foot-by-Foot Geometry Measurements Collected Between Los Angeles, CA, and Oakland, CA, September 23–24, 2013

Geometry Parameter	Mean Difference	Standard Deviation
Gage (Inches)	-0.00627	0.02865
Crosslevel (Inches)	0.05907	0.05386
Curvature (Deg/100')	-0.00872	0.05733
L Profile 31' (Inches)	0.00003	0.03736
R Profile 31' (Inches)	0.00005	0.03662
L Alignment 31' (Inches)	0.00007	0.02970
R Alignment 31' (Inches)	0.00004	0.03024
L Profile 62' (Inches)	0.00003	0.03983
R Profile 62' (Inches)	0.00003	0.03912
L Alignment 62' (Inches)	0.00004	0.03397
R Alignment 62' (Inches)	0.00001	0.03383
L Profile 124' (Inches)	0.00006	0.04260
R Profile 124' (Inches)	0.00005	0.04175
L Alignment 124' (Inches)	0.00005	0.05628
R Alignment 124' (Inches)	-0.00000	0.05616

(Results outside expected acceptable limits are shown in red/underline font)

Successful operation of ATGMS throughout the 2013 Amtrak Assessment program constituted conclusion of Stage 2 efforts. Evaluation of system performance during the 2013 Amtrak Assessment resulted in a series of recommendations for hardware and software enhancements targeted at improving ATGMS reliability as well as performance of the Remote Editor Console operations. These enhancements were addressed by FRA's RRS as the use of the remote measurement system was integrated into its standard operations.

3.2.4 *Conclusions and Lessons Learned*

Stage 2 efforts resulted in the successful demonstration of FRA's ATGMS on standard rail equipment while running in typical revenue service. ATGMS was re-engineered to allow for transmission of foot-by-foot raw geometry measurements to servers for processing, evaluation and distribution to survey stakeholders. Other key features of the technology that were either developed or refined during this stage included:

- Automated health and status reporting
- Self-diagnostics and auto-recovery features
- Improved hourly "status" email messages that provided detailed system and survey information
- On-demand "Alert" messages that automatically report sensor malfunction

- Self-diagnostic and auto-recovery features on the Data Collection Module to detect communication issues, corruption of data or configuration files, etc., and initiate a pre-defined sequence of actions to shutdown and restart the system.

A comparison of track geometry collected by ATGMS to that collected by the manned system onboard FRA's DOTX 220, illustrated that the two systems produced data of equal quality with differences between measured geometry data within acceptable limits established for measurements from multiple vehicles for this effort (see Table 4, Appendix A). Statistics of differences between multiple geometry surveys on selected track segments within short time periods showed that measurements collected with ATGMS were relatively (see Table 6, Appendix B). Exceptions generated by ATGMS and the manned system were compared and differences in reporting were attributed to several causes, among them being the speed-based class of track determination originally employed by ATGMS approach, and the automated exception validation logic used with ATGMS. To address these issues, ENSCO established a Remote Editor Console to allow for review of ATGMS-reported exceptions by experienced personnel in order to provide an additional level of quality assurance for results transmitted to FRA and railroad personnel. Although refinements and enhancements continued following the formal end of this stage, the performance of the system was such that FRA adopted this technology and employed it during FRA's RRS evaluations of Amtrak passenger routes starting in 2013.

3.3 Stage 3: Advanced Measurement Technology Development

Stage 1 testing revealed that the use of a truck-mounted measurement beam design has several drawbacks, including interference with truck or axle maintenance as well as the need for custom-made support structures. FRA initiated Stage 3 efforts in July 2011 to develop sensor technologies that facilitated the design of a carbody-mounted ATGMS, and to demonstrate that design in passenger service operations. A carbody-mounted ATGMS offers the benefits of minimal interference with truck and wheel maintenance activities, improved protection of the measurement platform from flying debris, and flexible installation on a wide range of vehicle designs resulting in reduced installation and maintenance costs as compared to traditional truck-mounted approaches.

Working in partnership with FRA, Amtrak offered use of Amfleet I passenger car 82602 as the host vehicle for the carbody-mounted ATGMS. The vehicle is shown in Figure 28.

Figure 28: Stage 3 ATGMS Host Vehicle, Amtrak 82602

Selection of Amtrak's 82602 as the host vehicle was based on its ability to provide HEP to ATGMS and joint operations on the NEC with Amtrak's track inspection vehicle designated as 10002. Amtrak's 10002, shown in Figure 29, carries a truck-mounted track geometry measurement system and is manned by a typical operations crew.

Figure 29: Amtrak's Manned Inspection Vehicle, Amtrak 10002

3.3.1 *Stage 3 Goals*

The Stage 3 goal was to develop and demonstrate new sensor technologies and processing algorithms to support a carbody-mounted ATGMS. ATGMS performance would be evaluated by comparing the quality of collected foot-by-foot geometry measurements and reported exceptions with data collected using the traditional truck-mounted, manned geometry measurement system aboard Amtrak's 10002.

3.3.2 *Stage 3 System Development and Configuration*

Migration from the Stage 1 and 2 truck-mounted ATGMS to a carbody-mounted system required numerous hardware and software modifications. Design considerations for the carbody-mounted ATGMS included:

- **Laser Scanning Sensor** – The central consideration for the carbody-mounted system was the laser scanning sensors design. Features of the sensors employed in the final version of the system included the following:
    - The lasers within the sensors had sufficient power to illuminate the rail from a higher location as compared to that associated with a truck-mounted system.
    - The sensor was designed to have sufficient visual range in both distance and viewing angle to maintain an image of the rail despite relatively large motion of the instrumentation beam relative to the track. Vehicle dynamics and track geometry on the NEC were used to establish range requirements corresponding to ±2 inches vertical/lateral motion of the measurement beam and ±3 degrees of carbody roll.
    - The lasers within the sensor were rated to be Class 3R, considered safe if handled carefully with restricted beam viewing. This requirement was established to maintain safety. The measurement system was configured to turn off laser power when the vehicle speed dropped below a configurable threshold. In addition, provisions for protective covers were included in the design of the measurement beam to shield the lasers from accidental viewing by railroad personnel or the public.

    Algorithms for data processing services were modified to account for the extended-range laser scanning sensors as well as overall carbody dynamics.

- **Instrumentation Beam Design and Mounting Approach** – ENSCO designed the ATGMS instrumentation beam to meet its fundamental requirements—housing inertial sensors, securing laser scanning sensors in the optimum location, providing protection from the environment while maintaining adequate access to all sensors and electronics for ease in servicing—while featuring a modular concept that allowed for convenient mounting to a wide range of vehicles.

  The final design of the carbody-mounted instrumentation beam is shown in Figure 30. The beam assembly is composed of the main aluminum weldment beam that houses the collection of sensors, an ALD sensor used to detect the location of switches, and a set of four mounting brackets for connection to the carbody.

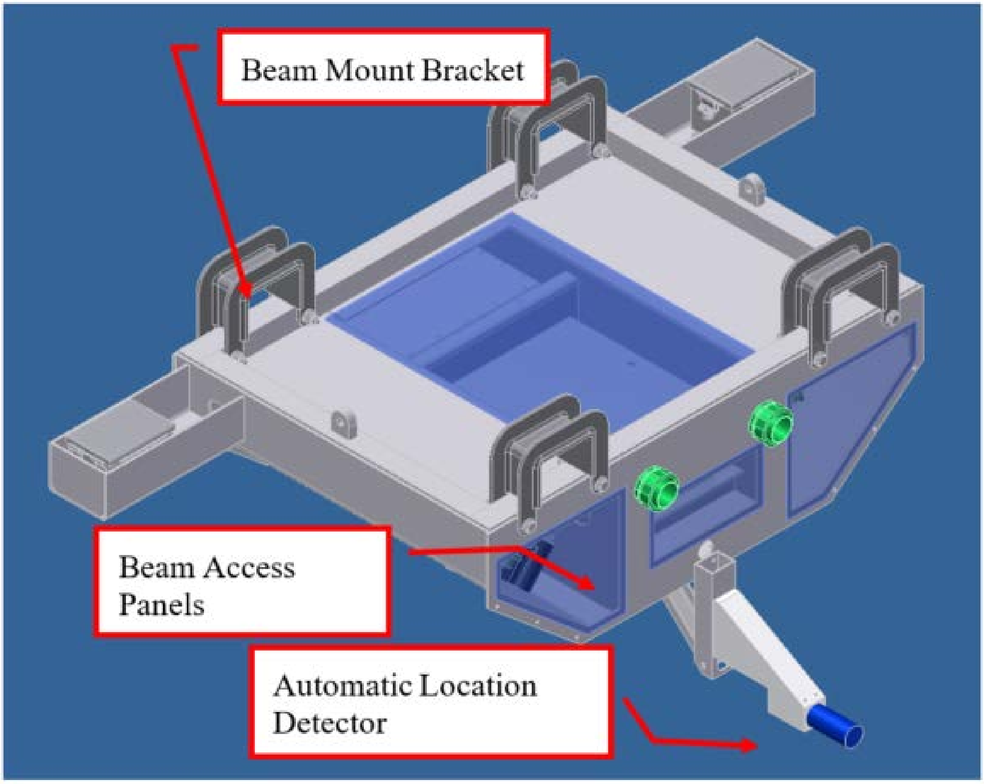


Figure 30: ATGMS Carbody-Mounted Instrumentation Beam

To attach the instrumentation beam to the vehicle, ENSCO designed a mounting frame assembly that is illustrated in Figure 31. The beam mount brackets shown in Figure 30 were designed to install around members of the beam mounting frame shown in Figure 31 by directly bolting the mount brackets to the frame. The beam mounting frame was attached to the center sill and crossbearer of the carbody floor using bolted connections. In case of primary connection hardware failure, the brackets will drop onto the beam mounting frame members preventing the beam assembly from dropping below the clearance profile for the vehicle. Illustrations of the overall mounting approach are provided in Figure 32. The benefits of this design are highlighted by the minimal interference with existing components of the vehicle and a relatively simple beam mounting frame.

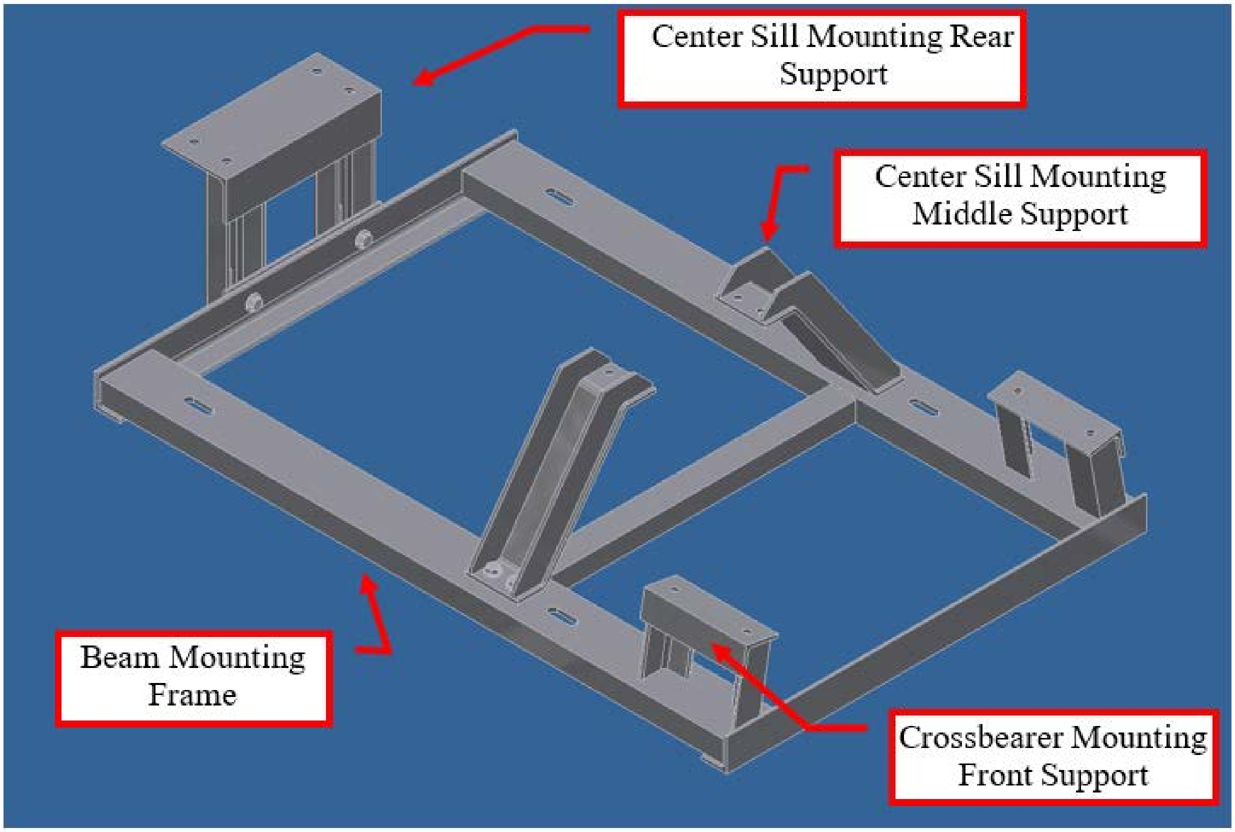


Figure 31: Custom Mounting Frame Assembly

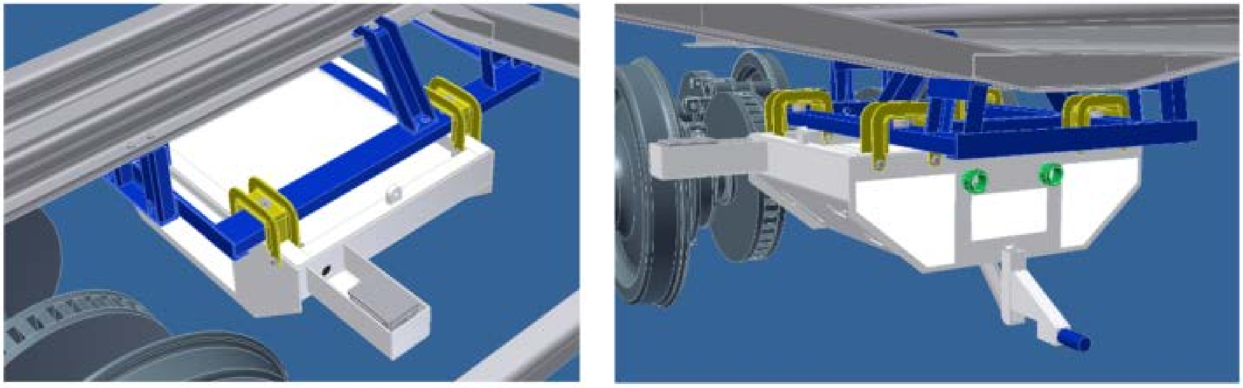


Figure 32: Illustrations of Mounting Approach for Carbody-Mounted ATGMS

- **ATGMS Electronics and Enclosure** – Minimal modification of the host vehicle was one of the goals of the carbody-mounted ATGMS design approach. Therefore, all electronics associated with the geometry measurement system were located on the exterior of the Amtrak vehicle. All data acquisition, signal conditioning and communication electronics were in a single enclosure depicted in Figure 33. Similar in design to the electronics enclosure employed in Stage 2 efforts, the enclosure employed in Stage 3 featured passive ventilation to increase heat transfer to maintain operational temperatures for components within the enclosure. Filter material was used with the air intake near the bottom of the enclosure and exhaust vent near the top of the enclosure to minimize the introduction of dust, dirt, moisture, and debris into the enclosure.

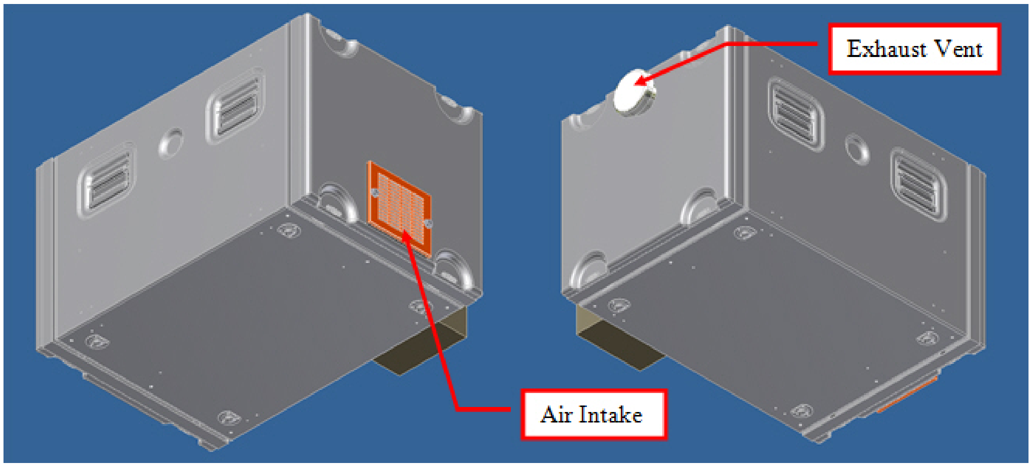


Figure 33: Carbody-Mounted ATGMS Electronics Enclosure

ENSCO employed mounting braces designed to be similar to auxiliary equipment mounting cross braces used on Amtrak equipment. Two such mounting braces were added to the underframe of the Amfleet I between existing structural members. A saddle designed to support the electronics enclosure was attached to the mounting braces. This arrangement is illustrated in Figure 34.

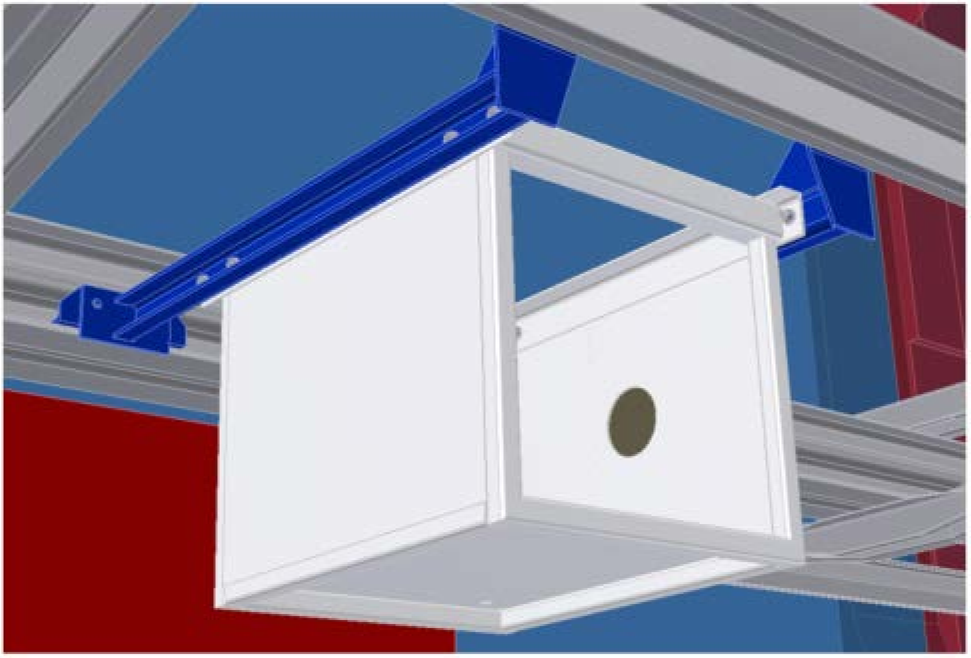


Figure 34: Electronics Enclosure Saddle and Mounting Braces

Amtrak provided vehicle HEP to the instrumentation through the vehicle's circuit breaker box. A dedicated circuit breaker, a transformer, and an automatic power switch were installed inside the existing electrical cabinet interior of the car near the B-end. All other elements of the power and electronics were located on the exterior of the vehicle. The final installation of the electronics enclosure is depicted in Figure 35.

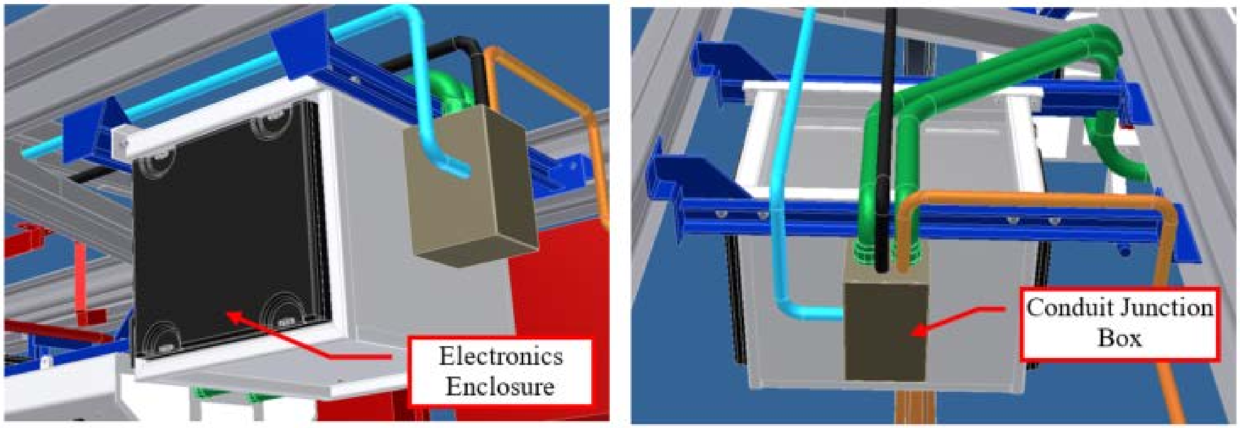


Figure 35: Illustration of ATGMS Electronics Enclosure Installation

- **Tachometer Assembly** - ENSCO implemented a tachometer mounting scheme based on the approach employed on the Budd Pioneer III truck on Amtrak's 10002 inspection car, as shown in Figure 36. The mounting arrangement utilized a channel arm that extends out from an attachment point located on the truck frame to provide a mounting surface for the stator portion of the encoder. This arm is designed to rotate about its attachment point to provide enough flexibility to allow the encoder to follow the slight vertical movement of the axle resulting from the flexing of the primary suspension. A rubber isolator was utilized at the pivot joint of the channel arm to compensate for any lateral movement of the axle. The encoder mount employs a bolt-on adapter that contains an isolated shaft that connects the axle to the encoder itself. ENSCO designed a safety catch system to prevent the parts from falling beyond the clearance envelope.

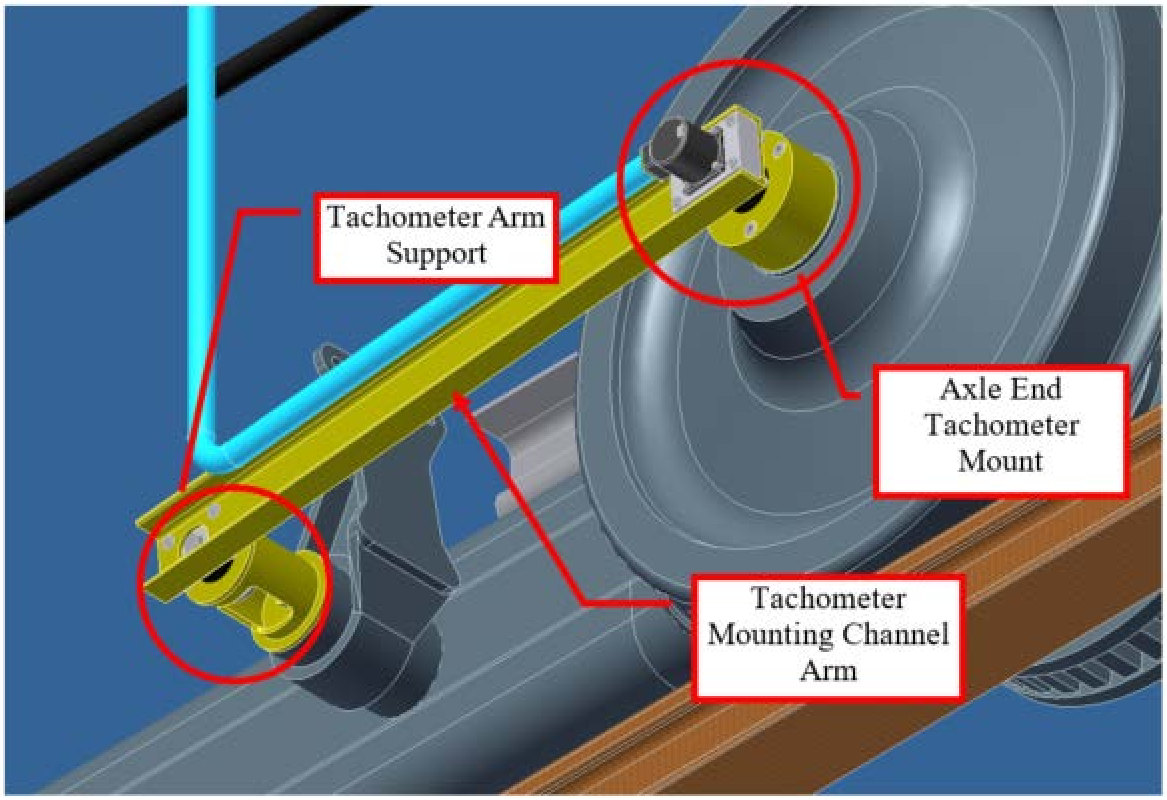


Figure 36: Amtrak's 82602 Tachometer Assembly Layout

Detailed stress analyses were conducted on all mechanical components. ENSCO installed the components presented in this section at Amtrak's Ivy City Maintenance Facility under the supervision of Amtrak personnel. GPS and cellular antennae were mounted on the roof of the host Amfleet I railcar at the A-end of the car as close to the car's centerline as possible. Figure 37 depicts the final layout of ATGMS components on Amtrak Car 82602; photographs of the installation are provided in Figure 38.

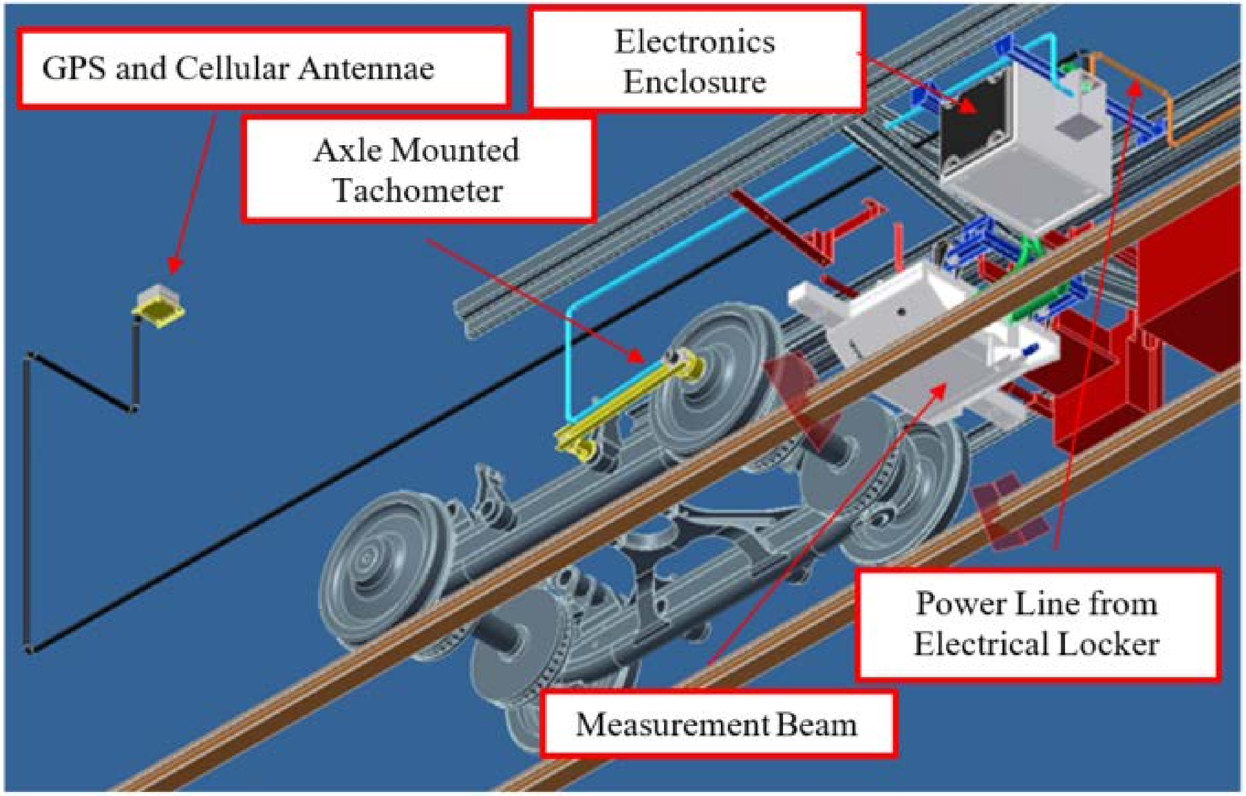


Figure 37: Carbody-Mounted ATGMS Configuration on Amtrak's 82602

Figure 38: Stage 3 Carbody-Mounted ATGMS Installation, Amtrak's 82602

Installation of the carbody-mounted ATGMS on Amtrak's 82602 was completed and accepted in August 2012. The system was commissioned immediately following installation by undergoing standard geometry car repeatability tests.

The carbody-mounted ATGMS operational approach was the same as that used during the initial efforts conducted under Stage 2 testing. All geometry data was transmitted to TrackIT® servers while exception reports, as well as status messages, were sent to ENSCO for analysis and review. The Remote Editor Console developed in the latter parts of Stage 2 development was not used during testing of the carbody-mounted system as the system development was not completed in time.

3.3.3 *Stage 3 Testing*

Amtrak operated Car 82602 as part of passenger revenue service on NEC, covering more than 50,000 miles between October 2012 and August 2013. Two round-trip surveys between Washington, DC, and Boston, MA, were conducted with ATGMS operating in the same consist with Amtrak's 10002 track inspection vehicle to evaluate the performance of the carbody-mounted system compared to that of a traditional truck-mounted system.

The first survey was conducted on October 21 and 22, 2012, and the results were used to adjust the ATGMS software. The data from the October 2012 tests indicated a problem with the tachometer assembly. ENSCO added reinforcements to the mounting system to eliminate stress on the electrical and mechanical connections.

The second survey was conducted on April 2 and 3, 2013. Foot-by-foot geometry measurements and geometry exception data generated between New York, NY, and Washington, DC, on April 3, 2013, were used to evaluate and document ATGMS performance with results from Amtrak's 10002 considered as the ground truth. It is important to note the following operational differences between the two survey vehicles during the April 2–3 survey:

- Amtrak's 10002 employed its inspection car crew to review exceptions identified by Amtrak's measurement system. ATGMS relied on an automated exception editor designed to identify candidate geometry exceptions and accept or reject events as "true" exceptions based on a set of mathematical rules. The manual geometry review process employed by the Amtrak approach relies on the operator's experience and ability to observe both track and environmental conditions when deciding if an event is a "true" exception or not.
- Personnel onboard Amtrak's 10002 were able to confirm proper track class designation. During NEC survey operations, ATGMS relied solely on vehicle speed to the determine class of track to identify geometry exceptions. Therefore, ATGMS is prone to declare a lower class of track if the train speed is below the posted speed, creating discrepancies in exception detection results

The analysis of the exceptions generated by both the ATGMS and Amtrak's 10002 during the April 2-3, 2013, survey is detailed in ENSCO Document SERV-REPT-0000528, provided in Appendix C; over which Amtrak's 10002 reported 63 exceptions. Not all ATGMS-generated exceptions matched the 63 exceptions. Mismatched exceptions were reviewed and associated with one of the following causes:

- Small differences in geometry measurements collected by the two systems
- Track class determination
- Cases of erroneous data in the ATGMS gage system
- Cases of missing GPS data in Amtrak's 10002 survey data analyzed

Alternatives to speed based determination of track class, such as detailed track maps based on railroad-provided information or real-time updating of information through a utility like the web-based application developed during Stage 2 activities, would provide additional quality control measures. Details regarding the exception analysis can be found in Appendix C.

As was done in Stage 2 efforts, geometry exceptions were used as markers for retrieving corresponding foot-by-foot geometry data collected by ATGMS and Amtrak's 10002 for detailed analysis. Analysts compared measurements collected over more than 17,500 feet of track located throughout the NEC. Results of this effort are shown in Table 7 (taken from Appendix C).

Table 7: Statistics of Difference between ATGMS and 10002 Foot-by-Foot Track Geometry Data, April 2013

Geometry Parameter	Mean Difference	Standard Deviation
L Profile 31' (Inches)	0.00000	0.0439
L Profile 62' (Inches)	-0.00000	0.0455
L Profile 124' (Inches)	0.00032	0.0523
L Alignment 31' (Inches)	0.00017	0.0394
L Alignment 62' (Inches)	0.00018	0.0614
L Alignment 124' (Inches)	-0.00000	0.1195
R Profile 31' (Inches)	0.00015	0.0559
R Profile 62' (Inches)	0.00000	0.0579
R Profile 124' (Inches)	0.00044	0.0689
R Alignment 31' (Inches)	0.00000	0.0649
R Alignment 62' (Inches)	0.00000	0.0786
R Alignment 124' (Inches)	-0.00030	0.1293
Crosslevel (Inches)	-0.02105	0.0975
Curvature (Deg/100')	0.00962	0.0528
Gage (Inches)	0.05663	0.0554

(Results outside expected acceptable limits are shown in red/underline font)

Except for the mean difference of gage and standard deviation of crosslevel measurements, statistical measures for all other measurement parameters met repeatability expectations. Both gage and crosslevel measurements can be typically addressed through reevaluation of offsets on a routine basis. Testing demonstrated that the carbody-mounted ATGMS produced data of equal quality when compared with that of a truck-mounted track geometry measurement system.

The carbody-mounted ATGMS was operated in revenue service on the NEC until August 2013. The ATGMS was periodically inspected at Amtrak's Ivy City Maintenance Facility. The system required minimal maintenance.

3.3.4 *Conclusions and Lessons Learned*

During Stage 3 ATGMS operations on Amtrak Car 82602, it was illustrated that the carbody-mounted system yielded all benefits expected over the previous truck-mounted track geometry measurement systems. The increased clearance between track and measurement beam minimized interference with truck and wheelset maintenance activities, and decreased the debris fouling of the laser and camera lenses. This tested the potential for ATGMS installation on a wide range of vehicles with reduced installation and maintenance costs.

Additional efforts to provide passive lens protection are envisioned to further reduce the amount of dirt reaching the optics, thus prolonging the time between scheduled maintenance activities. The passive ventilation built into the electronics enclosure did not have an appreciable effect on electronics performance; it did, however, introduce accumulated dust, dirt, and debris within the enclosure

3.4 Stage 4: Energy Harvesting Technology Development

In previous development stages, the ATGMS was installed on passenger rolling stock that provided sufficient electrical power to operate the measurement systems. Wide-scale deployment of ATGMS technology requires energy harvesting technologies that facilitate installation of unattended measurement systems on freight rolling stock without electrical power. Stage 4 of the ATGMS technology development plan was initiated in April 2011 to arrive at a specification for a system that could provide power to a typical ATGMS installation using a variety of power sources.

3.4.1 *Stage 4 Goals*

The goals of this stage were to arrive at the design, and system specification, for a self-contained, reliable, partially regenerative electrical power system (EPS) for ATGMS operations suitable for installation on a wide range of freight cars. In addition, the power system cannot interfere with normal operations of the host vehicle. Performance requirements for the envisioned system included:

- Minimum 200-watt continuous output power with power quality suitable for battery charging and direct powering of sensitive electronic devices.
- Energy generation sources considered, included diesel fuel, solar power and wind energy harvesting technology for battery charging with emphasis on minimizing reliance on diesel fuel.
- Automatic mixed power system control, charging, distribution, health monitoring and reporting.
- Mechanical design suitable for freight railroad environment and installation on rail car under floor assembly. The battery system may be designated for interior location.
- 90-day maintenance interval.

3.4.2 *Stage 4 Development*

ENSCO worked with New Way Solutions, LLC, throughout Stage 4 activities to specify requirements for an ATGMS-suitable energy harvesting power system. Previous research by New Way Solutions, under FRA contact, focused on the development and demonstration of a prototype energy harvesting power plant. During its early efforts, New Way Solutions developed an innovative power management electronics package that was not only considered a significant component within the requirements specification but also served as a test platform for wind energy harvesting tests conducted by New Way Solutions during Stage 4 efforts.

During Stage 4, ENSCO and New Way Solutions investigated:

- Operational and environmental conditions to be encountered by ATGMS, including vehicle speeds, wind conditions and solar radiation values, based on measured operational parameters and historical weather conditions
- Appropriate temperature, mechanical, and safety requirements for the equipment
- Features of candidate components, including batteries, solar panels and diesel generators as well as charge control system characteristics
- The likely contributions of wind energy harvesting to a deployed system
- Simulated electrical load inputs and outputs based on a computer-based model employing measured operational and environmental conditions.

Specifications were developed for a power system including recommendations for the size and number of components that would ensure 100% uptime of an ATGMS in typical freight operations.

New Way Solutions evaluated two types of wind turbines for railroad applications. The first design consisted of a rectangular air intake and a horizontally configured turbine with permanent magnet alternators (PMA) installed on each end of the turbine as shown in Figure 39. An axial turbine with a conical air intake prototype, as shown in Figure 40, was also evaluated. Over-the-road tests conducted in the fall of 2011 involving mounting the turbine arrangements on a pick-up truck to test the power generation as a function of air speed and wind direction at speeds up to 70 mph.

Figure 39: Horizontal Turbine and Rectangular Air Intake Configuration Prototype

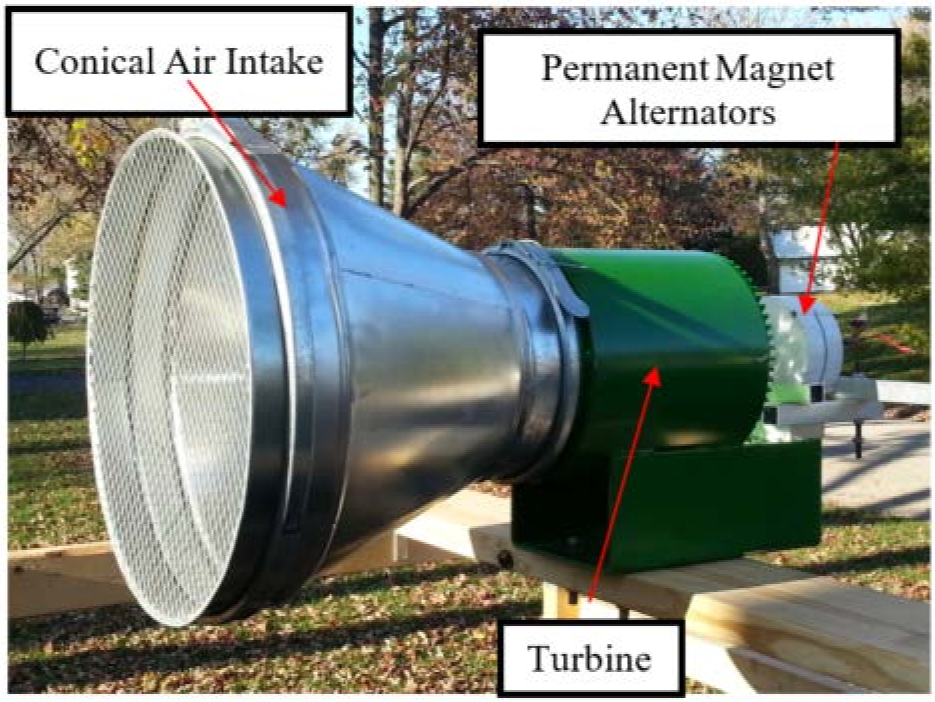


Figure 40: Axial Turbine and Conical Air Intake Configuration Prototype

Test results indicated that a wind turbine with rectangular air intake did not produce any measurable power throughout the entire speed range. The axial wind turbine with conical air intake produced a measurable power output at speeds above 30 mph. Given that typical freight trains spend much of their time traveling at speeds lower than 30 mph, it was concluded that wind power could not be used effectively as a source of power for ATGMS in freight operations.

Results obtained from an analysis of solar energy availability and fossil fuel power sources were input into a computer model developed for a parametric analysis of the overall EPS configuration. Variables in this model included:

- Number of solar panels
- Size of battery banks
- Fuel capacity of diesel generators acting both as one component of a power system and acting as the main source of power in the absence of alternative sources
- Percentage of battery bank depth of discharge (DOD)

Figure 41 illustrates the architecture of the power system resulting from the analysis. A key feature of the recommended system is the charge controller designed to autonomously manage the power generated by all sources to properly charge the battery bank and provide 100% uptime power to the ATGMS. The charge controller designed for this application can:

- Accept a maximum of forty 12-volt solar panels with a maximum rating of 5 kW
- Accept a diesel generator with a maximum rating of 3 kW
- Monitor the overall power system and generate status messages that can be transferred as part of ATGMS data via cellular communications

- Charge the battery banks using only solar power
- Turn the diesel generator on or off
- Accommodate other sources of power in the future. This accommodation was critical as FRA required that the power system be flexible to changes necessitated by operating scenarios and other drivers.

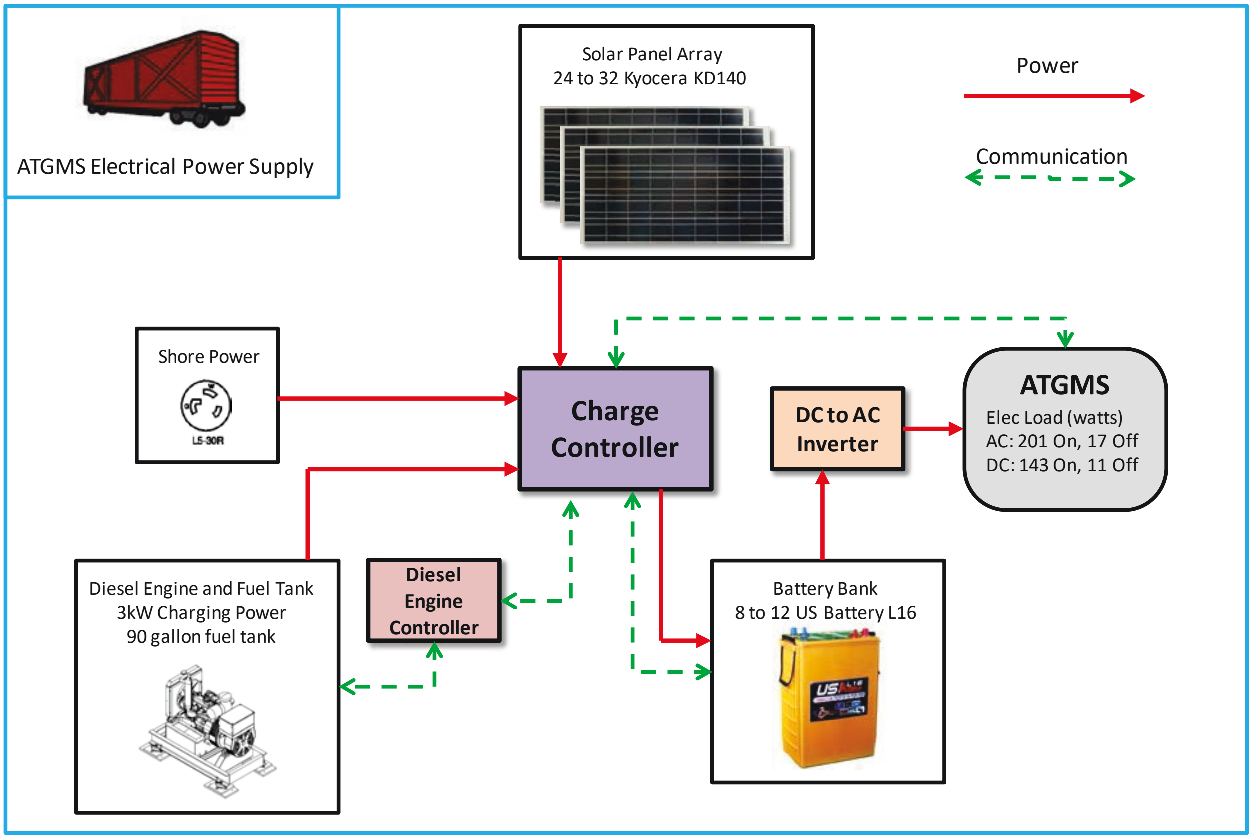


Figure 41: Proposed Electrical Power System Architecture

Details regarding the recommended configuration of the power system, along with other conclusions from this stage of research, are provided in the following section.

3.4.3 *Stage 4 Conclusions and Lessons Learned*

A computer model was used to evaluate several arrangements of the power production components. The resulting recommended designs are shown in Table 8.

Table 8: Summary of Electrical Power Supply Designs

Electrical Power Supply Design	Solar Power Components	Batteries	Diesel Generator	Notes
Conservative Approach	32 Kyocera KD140 solar panels	12 US Battery L16 batteries	1 diesel generator that can produce 3kW of charging power with a fuel consumption rate of 0.8 gallon/hr or less 90 gallon fuel tank	Arrangement will work with AC or DC ATGMS Assumes 2 hr wait period after stopping for shutdown
Efficient Use of Diesel to Reduce Solar and Battery Components	24 Kyocera KD140 solar panels	8 US Battery L16 batteries	1 diesel generator that can produce 2kW of charging power with a fuel consumption rate of 0.8 gallon/hr or less 135 gallon fuel tank	Arrangement will work with AC or DC ATGMS Assumes 2 hr wait period after stopping for shutdown
No Diesel Generator, Only Solar Panels and Batteries	32 Kyocera KD140 solar panels	12 US Battery L16 batteries	No diesel generator	Requires DC ATGMS Between 0.5 to 2 hr wait period after stopping for shutdown based on queued transmitted messages

The design and analysis process conducted within Stage 4 yielded several different conclusions and recommendations that will serve not only this effort, but will be a guide for similar activities.

1. Test results indicated that a wind turbine would not produce sufficient power for speeds typical of freight operation. Therefore, wind harvesting it is not recommended for use with an ATGMS mounted to a freight vehicle. However, a wind turbine was able to produce an appreciable amount of power at higher speeds such as those seen in passenger service. However, autonomous system use in passenger service generally does not require use of a power generation system.

2. Converting ATGMS to operate on DC power instead of AC power would have a significant improvement in performance.

3. Efficient use of a diesel generator needs to take into account the battery bank size, maximum power input accepted by the charge controller system, matching the charging run cycles to the required exercise cycles, sizing of the diesel generator itself and accommodations for a fuel supply. Features that will help decrease dependence on a diesel generator include some obvious choices, such as increasing the battery bank size, as well as other choices such as decreasing the shutdown wait time after the car stops and increasing the battery bank DOD in the charge plan.

These considerations led FRA to consider alternatives to diesel fuel generators, including methanol-based fuel cells.

Methanol is a liquid fuel that offers many advantages over diesel fuel. It is non-hazardous, with sensible precautions. Menthol is stable, has low volatility, and remains liquid over a broad temperature range. Fuel cells will require less routine maintenance than diesel generators, an important feature for unattended equipment. Methanol does not pose some of the long-term soil and water contamination issues as petroleum. Use of fuel cell technology allows for easier integration of the secondary power source into communication hardware. In addition, the use of fuel cells on an unattended vehicle allowed FRA to demonstrate the use of alternative fuels to the rail industry. For these reasons, FRA's freight car-based ATGMS used in Stage 5 efforts was equipped with a power system that employed both solar energy and direct methanol fuel cell technology as its primary and secondary sources of power for charging the ATGMS battery system.

3.5 Stage 5: Demonstration in Freight Service

In the final ATGMS development stage, FRA demonstrated ATGMS technology on a freight vehicle operating under typical revenue service conditions. The FRA carbody-mounted ATGMS was deployed on a standard box car and the system was demonstrated on short lines and regional railroads. Technology and procedures developed by FRA throughout the first four stages of this program were relied upon throughout these demonstrations.

The box car, DOTX 225, was purchased from Escanaba and Lake Superior Railroad (ELS) and refurbished and modified for ATGMS in October 2015. Images of the vehicle prior to and after refurbishment are provided in Figure 42. The vehicle was delivered to ENSCO's Chambersburg, PA, maintenance facility in February 2016 for system installation and testing.

(a) As purchased from ELS. **(b) Upon completion of refurbishment.**

Figure 42: FRA's Freight Boxcar DOTX 225

The ATGMS EPS was based on the system specified during Stage 4 efforts. The recommended design included the use of solar power as the primary charging method while using direct methanol fuel cell technology as a secondary source of power for charging the ATGMS battery system. While the methanol fuel cell technology was not tested during Stage 4 efforts, the testing performed under Stage 5 provided a suitable test bed to evaluate the technology. Communications with the charge controllers, the charger/inverter and the methanol fuel cells were configured so that remote monitoring and control of all components of the electrical system were available to the ATGMS operators.

The ATGMS freight service demonstration began in April 2016 and ran through January 2017.

3.5.1 *Stage 5 Goals*

The goals of this stage were to develop a self-powered freight car-based ATGMS system and demonstrate the system on short line and other freight railroads. ENSCO applied the results of the prior development stages for this effort.

3.5.2 *Freight Vehicle Configuration*

ENSCO worked with ELS on a refurbishment plan to prepare the boxcar for ATGMS integration. The vehicle was ballasted with fiber-reinforced concrete to bring it to an estimated weight on rail of 190,000 lbs. The carbody-mounted brake system was converted to a truck-mounted brake system to eliminate brake rod interference with the ATMGS beam. This required additional changes to the truck bolsters and side frames to allow the truck-mounted braking system installation. The wheelsets were also replaced, and reconditioned springs were installed in the suspension. Four-inch pipe was installed in the car prior to pouring the concrete floor to serve as a conduit to facilitate the installation of equipment under the car. Passive ventilation was provided through the addition of a roof as well as floor-level vents. Floor drains were installed along with a junction box for roof-mounted equipment. Boarding ladders and safety rails were added to the exterior of the vehicle to allow safe access to the interior of the vehicle. ELS also installed solar panel mounting brackets to the roof, painted and stenciled the car prior to delivery. Final refurbishment work is shown in Figure 43.

(a) Overall Car (b) Interior Preparations (c) Boarding System
Figure 43: ELS Refurbishments

3.5.3 *Instrumentation Beam Design and Mounting*

ENSCO designed a mounting assembly and measurement beam to account for the center sill of the boxcar. The final installation required a redesign of the Stage 3 measurement beam to allow for a new mounting structure, as well as to accommodate the sensor package design. Components used in previous stages were re-used when possible. For example, the computer rack used during Stage 3 housed the computer equipment inside the freight vehicle. The overall car layout is shown in Figure 44.

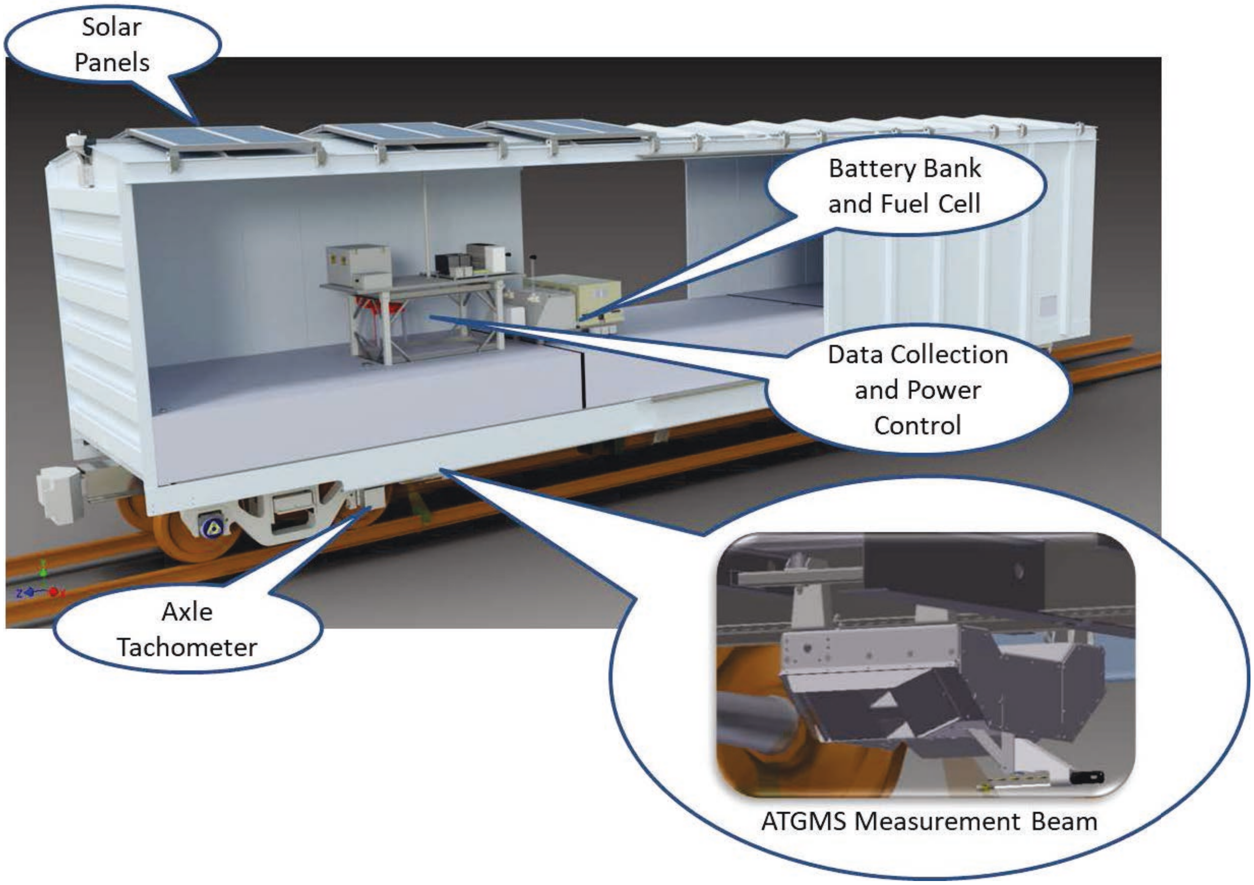


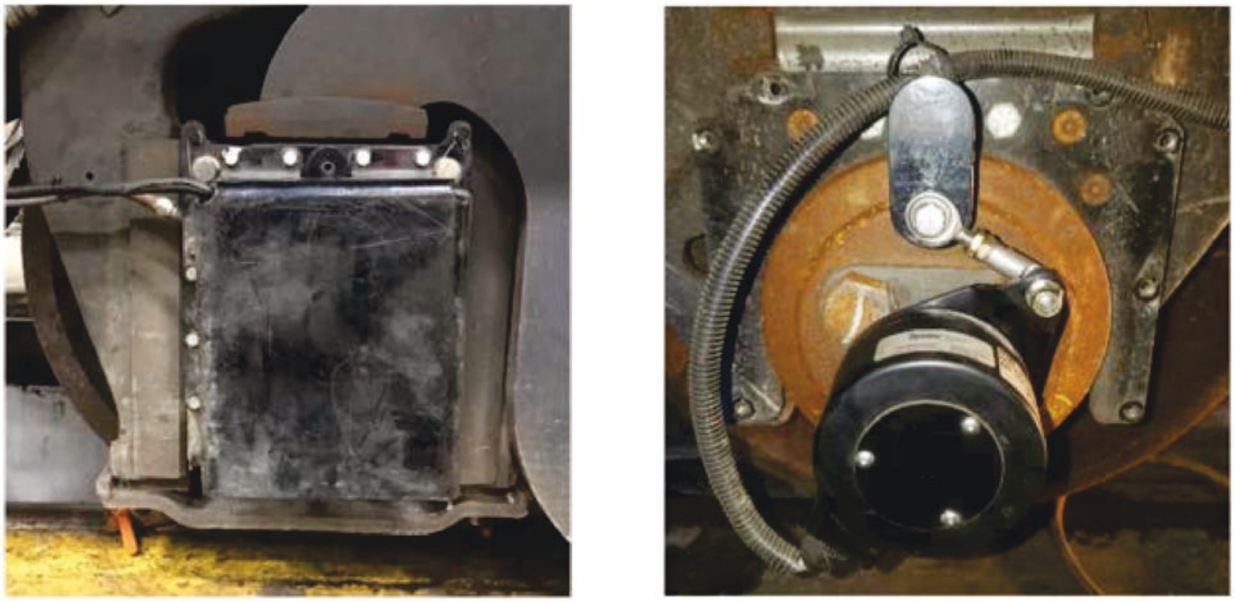
Figure 44: Arrangement of Measurement System and Electrical Power System Components in FRA's DOTX 225

The freight ATGMS was outfitted with the latest ATGMS beam configuration. The track geometry measurement system now employs digital signal processing techniques to reduce the signal noise and increase sensor stability. These improvements resulted in a more reliable and robust system. The digital system has a lower power draw as compared with the prior analog signal processing unit and the inertial sensors were consolidated into a single sensor package. The measurement beam is shown in Figure 45.

Figure 45: DOTX 225 Geometry Measurement Beam

3.5.4 *Tachometer Assembly*

The tachometer assembly was mounted on the left side of axle 2 on the A-end truck. A modified end cap with a built-in axle spike was installed by ELS in preparation for the tachometer installation. The tachometer design, shown in Figure 46, includes a tether to allow for lateral movement of the axle and a cover to protect the assembly from weather and impacts.



(a) Rock Cover **(b) Tachometer with Tether**

Figure 46: Tachometer Installation

3.5.5 *ATGMS Electronics Enclosure and Power System Installation*

ENSCO designed and fabricated a work table and electronics pallet to withstand significant force. The control components of the solar power system and the computer rack used in Stage 3 were installed on the work table inside the vehicle. The battery bank and fuel cell were installed on a customized battery pallet. The final installations of the table and battery pallet are shown in Figure 47.

Figure 47: Electronic Table and Battery Pallet

3.5.6 *ATGMS Power System*

DOTX 225 was equipped with a power system that employed both solar energy and direct methanol fuel cell technology as its primary and secondary power sources charging the ATGMS battery system. A schematic of the system architecture is illustrated in Figure 48. The power system consisted of 12 140W, 17.5V, 8A solar panels and a 110W EFOY Pro 2400 Duo methanol fuel cell with four cartridges powering a 24V battery bank consisting of 12 6V AGM batteries with a total power capacity of 22 kWh. The average load on the system was approximately 130 watts. Each solar charge controller controlled one six panel array of solar cells. Figure 49 shows the solar panels and other roof-mounted equipment including GPS and cellular antennas. Communications with the charge controllers, the charger/inverter and the methanol fuel cell were configured through a communications hub to enable remote monitoring and control of all components of the electrical system.

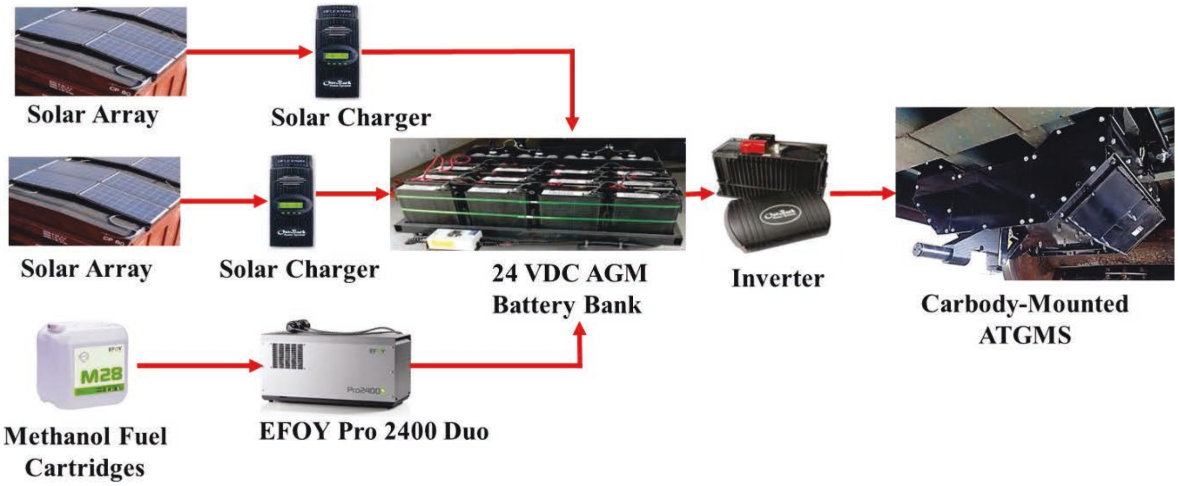


Figure 48: DOTX 225 ATGMS Power System Architecture

Figure 49: Roof-Mounted Equipment on DOTX 225

The power system performed without any issues during the 9-month demonstration. The solar charging system kept the batteries adequately charged with minimal need for the secondary fuel cell. In total, the fuel cell ran for 15 hours and consumed less than 1 liter of methanol. An illustration of the energy harvesting and usage throughout a 24-hour period is shown in Figure 50

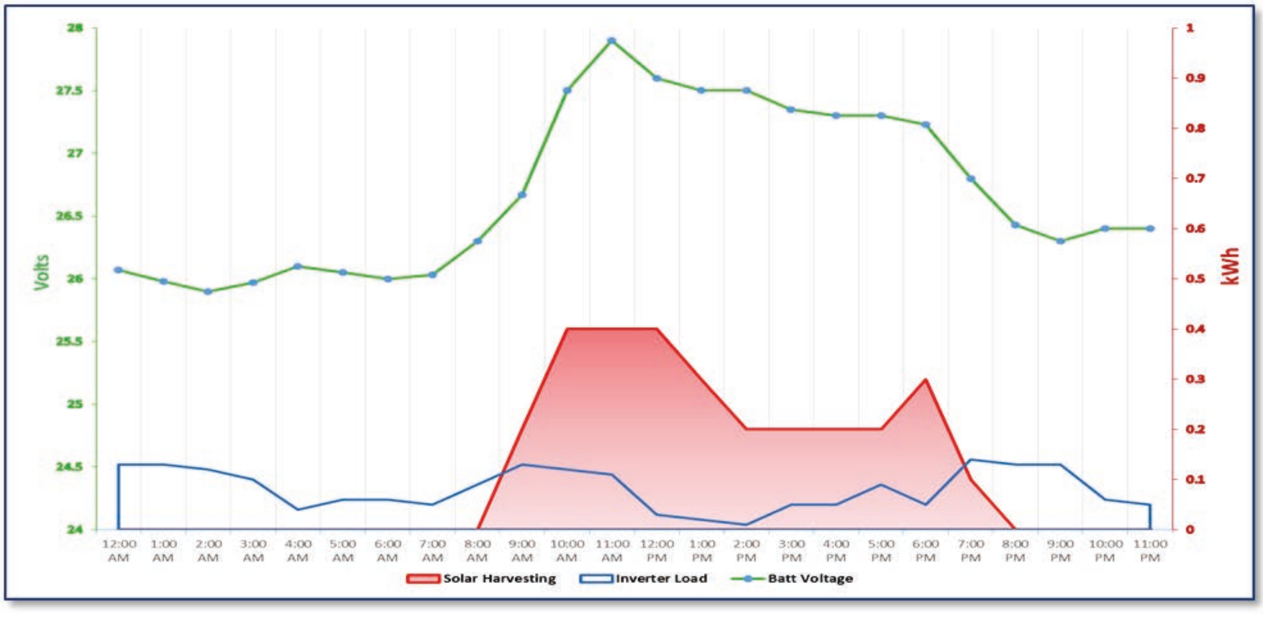


Figure 50: Performance of ATGMS Power System Over Typical 24-Hour Period

Installation of the measurement and power systems took place at ENSCO's Chambersburg maintenance facility between March 1 and March 30, 2016. Photographs of the power system are provided in Figure 51. Prior to releasing the vehicle for freight demonstration, the car underwent calibration and reproducibility analysis to verify the ATGMS performance. The results were within the acceptable standards established within FRA's Quality Assurance/Quality Control procedures.

Figure 51: Freight ATGMS Power System Installation

3.5.7 *Demonstration Test*

During the freight demonstration survey, the ATGMS box car was deployed nearly 300 days, surveyed over 12,700 miles, and provided track condition data for 29 railroads, including 25 short line railroads and four Class I railroads, as illustrated in Figure 52.

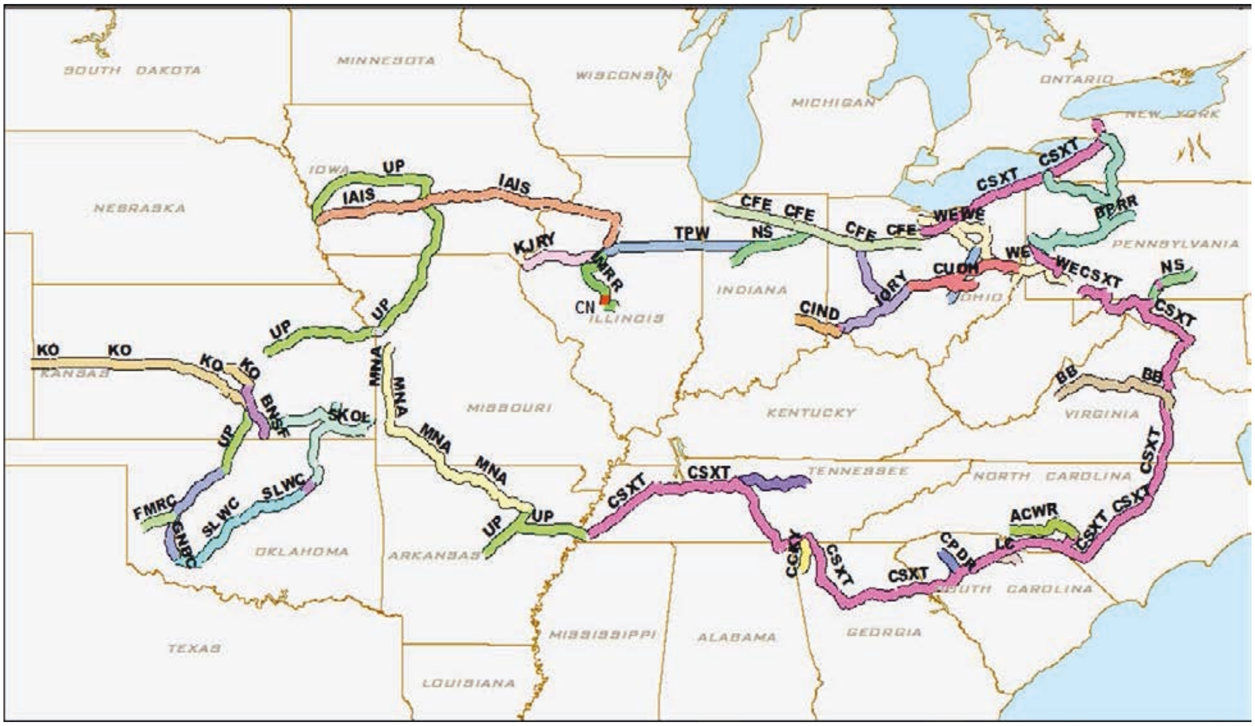


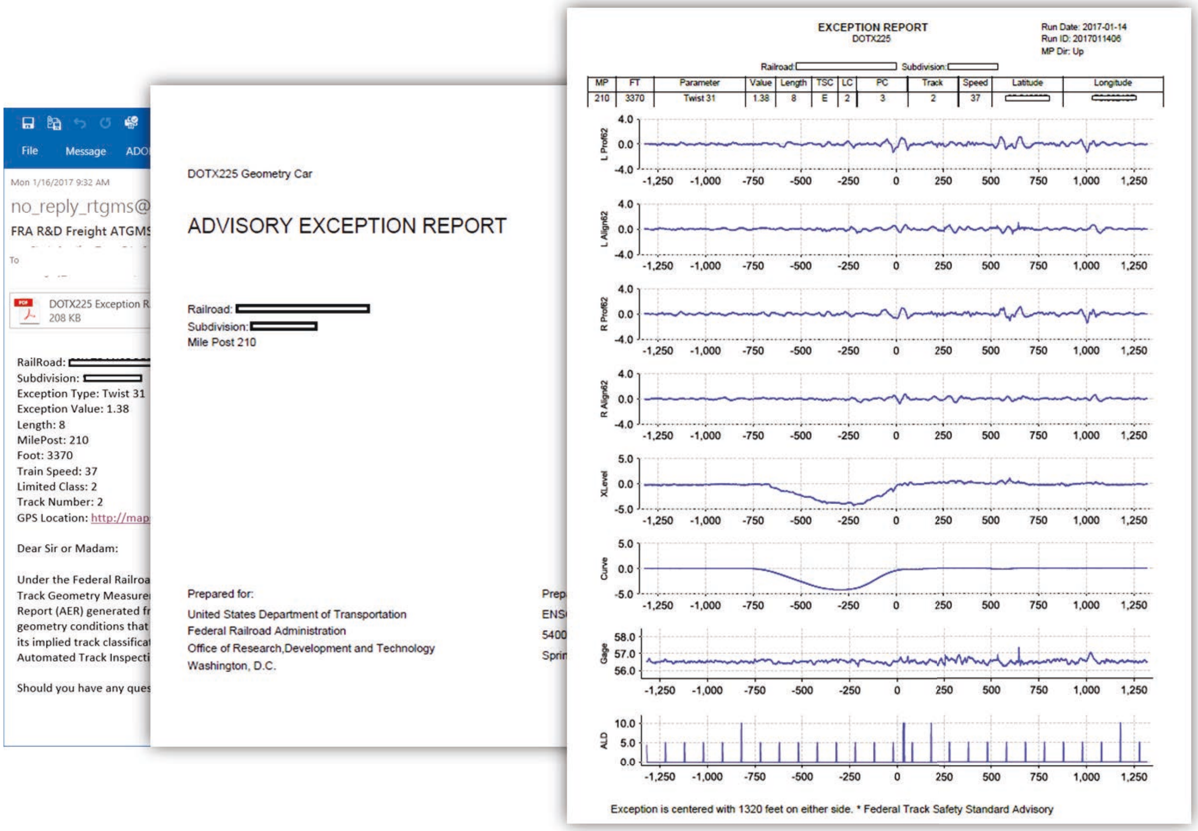
Figure 52: DOTX 225 Freight Demonstration Route

Participating railroads included:

- CSX Transportation
- Buckingham Branch Railroad
- Buffalo & Pittsburgh Railroad
- Wheeling and Lake Erie Railway
- Ohio Central Railroad
- Columbus and Ohio River Rail Road
- Ohio Southern Railroad
- Indiana and Ohio Railway
- Central Railroad of Indiana
- Chicago, Fort Wayne and Eastern Railroad
- Norfolk Southern Corporation
- Toledo, Peoria and Western Railway
- Keokuk Junction Railway
- Tazewell and Peoria Railroad
- Illinois and Midland Railroad
- Canadian National Railway
- Iowa Interstate Railroad
- Union Pacific Railroad
- Grainbelt Corporation
- Farmrail Corporation
- Stillwater Central Railroad
- South Kansas and Oklahoma Railroad
- Kansas and Oklahoma Railroad
- Missouri and Northern Arkansas Railroad
- Nashville and Eastern Railroad
- Chattooga and Chickamauga Railway
- Carolina Piedmont Railroad
- Lancaster and Chester Railway
- Aberdeen Carolina and Western Railway

Over the 12,787 miles of track tested by DOTX 225 during the demonstration, only 74.3 miles of data were not collected, resulting in a 99.994 percent success rate. The geometry system found approximately 20,000 “points of interest” based on railroad-defined exception thresholds. Several railroads requested that surveys be conducted one class higher than the posted class to identify areas for track improvements, while other railroads requested surveys at the posted class. Overall feedback from the railroads was positive with the participants often field-verifying the accuracy of the geometry exception locations and measurements. In some cases, survey stakeholders received automated track geometry testing for the first time, while others noted the benefits of conducing out-of-cycle tests without having to commit track engineering personnel.

The results of the inspection were delivered to survey stakeholders through the same reporting mechanism employed by FRA’s RRS during Amtrak assessment surveys. Data products included Advisory Exception Reports (AER), Track Condition Reports (TCR) and data strip charts. The AER, shown in Figure 53, was delivered via email to a pre-determined list specified by the participating railroad either on the same day as the survey or the next business day. The AER included the GPS and MP-based location, including a web link to Google Earth™, for an exception with the length and type in the body of the email. Attached to the email was a strip chart, in PDF format, with the foot-by-foot track measurements surrounding the exception. The TCR, shown in Figure 54, was emailed to the railroad representatives at the conclusion of the survey. The TCR provided an overall summary for the line segment, including the number of each type of exception found on the entire track segment, in a tabular format.



File
Message
ADO

Mon 1/16/2017 9:32 AM
no_reply_rtgms@
FRA R&D Freight ATGMS
To

DOTX225 Exception R
208 KB

RailRoad: [redacted]
Subdivision: [redacted]
Exception Type: Twist 31
Exception Value: 1.38
Length: 8
MilePost: 210
Foot: 3370
Train Speed: 37
Limited Class: 2
Track Number: 2
GPS Location: http://map

Dear Sir or Madam:

Under the Federal Railroa
Track Geometry Measure
Report (AER) generated fr
geometry conditions that
its implied track classificat
Automated Track Inspecti

Should you have any ques

DOTX225 Geometry Car

ADVISORY EXCEPTION REPORT

Railroad: [redacted]
Subdivision: [redacted]
Mile Post 210

Prepared for:
United States Department of Transportation
Federal Railroad Administration
Office of Research,Development and Technology
Washington, D.C.

Prep
ENS
5400
Sprin

EXCEPTION REPORT
DOTX225

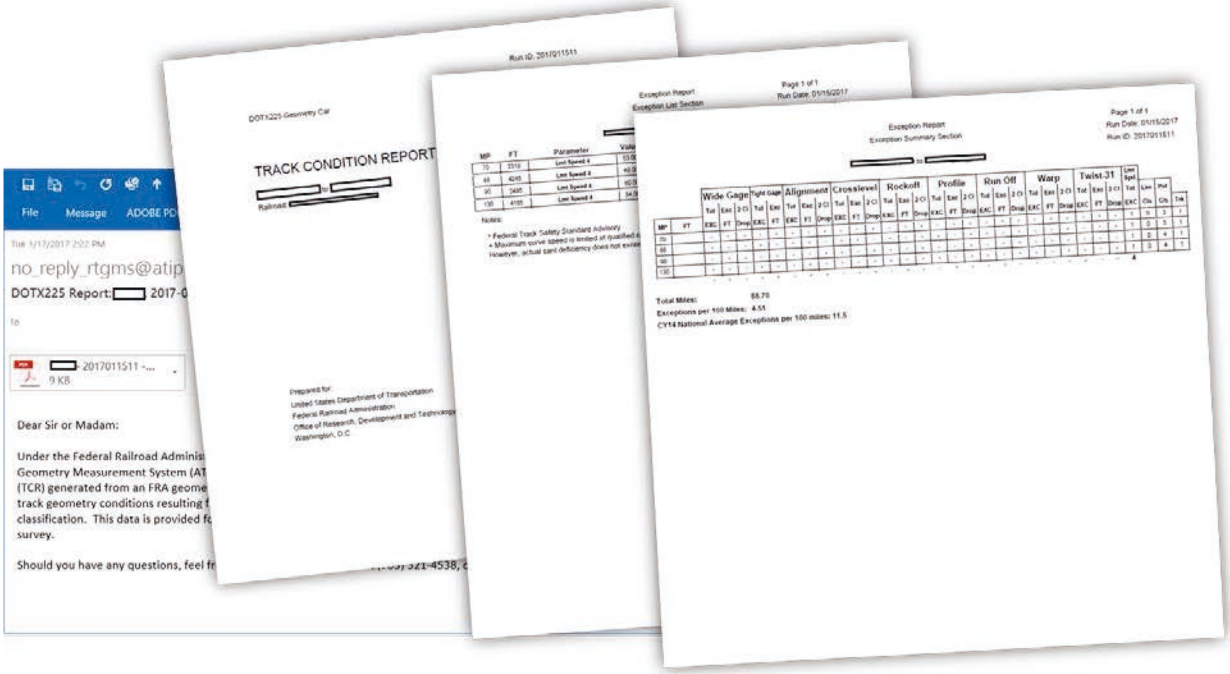
Run Date: 2017-01-14
Run ID: 2017011406
MP Dir: Up

Railroad: [redacted] Subdivision: [redacted]

MP	FT	Parameter	Value	Length	TSC	LC	PC	Track	Speed	Latitude	Longitude
210	3370	Twist 31	1.38	8	E	2	3	2	37	[redacted]	[redacted]

Exception is centered with 1320 feet on either side. * Federal Track Safety Standard Advisory

Figure 53: Example Advisory Excepion Report and Email



File
Message
ADOBE PD

Tue 1/17/2017 2:22 PM
no_reply_rtgms@atip
DOTX225 Report: [redacted] 2017-0
To

[redacted]-2017011511 -...
9 KB

Dear Sir or Madam:

Under the Federal Railroad Adminis
Geometry Measurement System (AT
(TCR) generated from an FRA geome
track geometry conditions resulting f
classification. This data is provided fo
survey.

Should you have any questions, feel fr

DOTX225 Geometry Car

TRACK CONDITION REPORT

[redacted] to [redacted]
Railroad [redacted]

Prepared for:
United States Department of Transportation
Federal Railroad Administration
Office of Research, Development and Technolog
Washington, D.C

Run ID: 2017011511

Exception Report
Exception List Section

Page 1 of 1
Run Date: 01/15/2017

Notes:
* Federal Track Safety Standard Advisory

Exception Report
Exception Summary Section

Page 1 of 1
Run Date: 01/15/2017
Run ID: 2017011511

[redacted] to [redacted]

Total Miles: 88.70
Exceptions per 100 Miles: 4.51
CY14 National Average Exceptions per 100 miles: 11.5

Figure 54: Example Track Conditioning Report

The accuracy of the ATGMS over the duration of the demonstration was assessed by comparing results from the initial reproducibility testing performed prior to the demonstration to a follow-up reproducibility test conducted at the end of the survey. The results for both tests are shown in Figure 55.

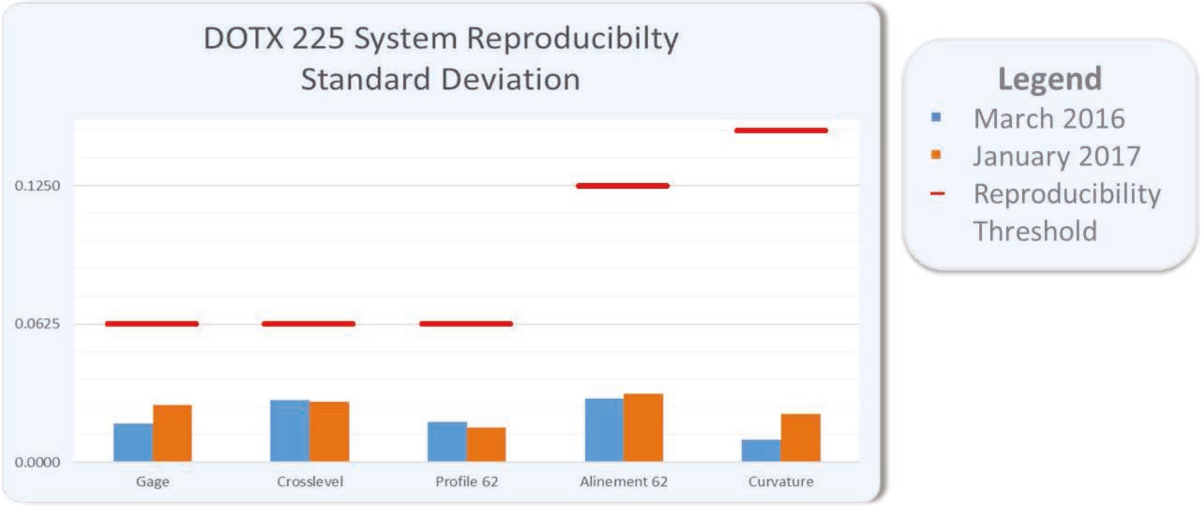


Figure 55: Comparison of Reproducibility Measurements from March 2016 and January 2017

The track geometry surveys collected over the same section of track at different times during the demonstration were compared to remotely verify system performance. An example of this type of comparison is shown in Figure 56. The two data traces were collected 38 days apart.

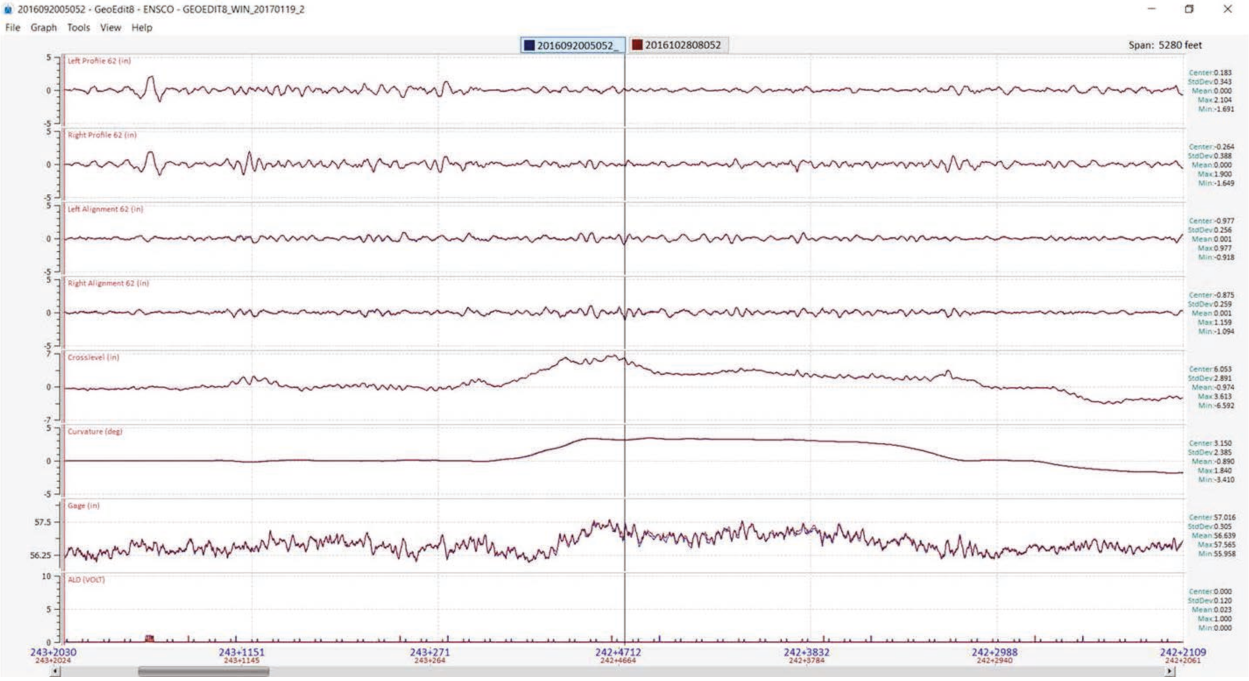


Figure 56: Example Overlay of DOTX 225 Survey Data Collected 38 Days Apart

Three maintenance visits were required during the 9-month demonstration. An initial visit was conducted shortly after the system began operations to resolve computer damage after the vehicle was "humped" in a yard. A second maintenance visit was conducted to perform a tachometer upgrade and to perform normal system maintenance. The final maintenance visit was conducted to resolve a computer error. Following this third maintenance visit, the system operated for 129 days without a visit.

3.5.8 *Conclusions and Lessons Learned*

Stage 5 efforts resulted in the successful demonstration of FRA's carbody-ATGMS on standard freight equipment while running in typical revenue service. The results of the freight service demonstration prove that ATGMS technology can be used effectively through freight interchange service to collect and distribute reliable track geometry data with little interference to revenue operations and minimal maintenance requirements. The track geometry data produced by ATGMS has proven to be accurate, and of equal quality to that of the manned geometry vehicles.

One opportunity for improvement in future carbody-mounted systems would be to include the rail profile images with the geometry exception data in the Remote Editing Console. Under certain conditions the carbody-mounted system's high angle of attack to the gage face increases the adverse effect rail head flow has on reporting narrow gage exceptions. The rail gage point is in the shadow of the gage face rail flow and is not measured correctly. Including a profile viewer would assist those reviewing and editing the data.

When comparing the operational support required for the demonstration test to traditional manned geometry car operations, ATGMS operations require minimal personnel support. ATGMS support activities included scheduling the surveys, coordinating the interchanges between railroads, gathering and creating the time table, and track chart and MP coordinates to build route tables. These tables were used to create the track centerline data, which correlated GPS coordinates and railroad identifiers within the autonomous geometry processing. In future testing, collecting this information prior to survey and creating accurate base maps prior to testing will alleviate some of the efforts required during testing. Other support responsibilities included monitoring the system, operating the Remote Editor Console, and distributing data to the stakeholders.

4. ATGMS-Related Analyses and Processes

Several processes have been developed to maximize the benefits and efficiencies of autonomous track inspection. The Remote Editor Console, employed by FRA to provide the highest level of quality control, is the most impactful of these processes. This section provides overviews of several other enabling processes developed and/or explored over the course of FRA's research program.

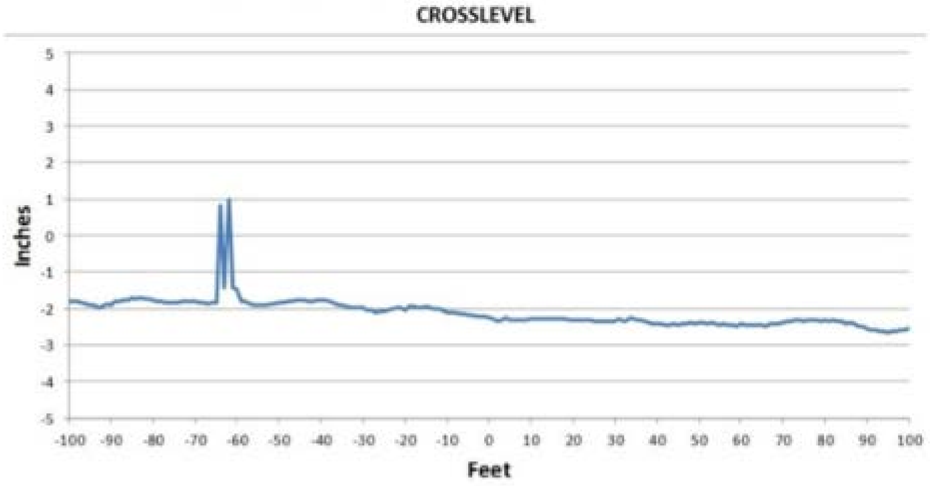
4.1 Exception Editing

Identifying and filtering exceptions is an important part of the quality control process. Automatic and manual techniques were employed to minimized the number of false exceptions in the data products.

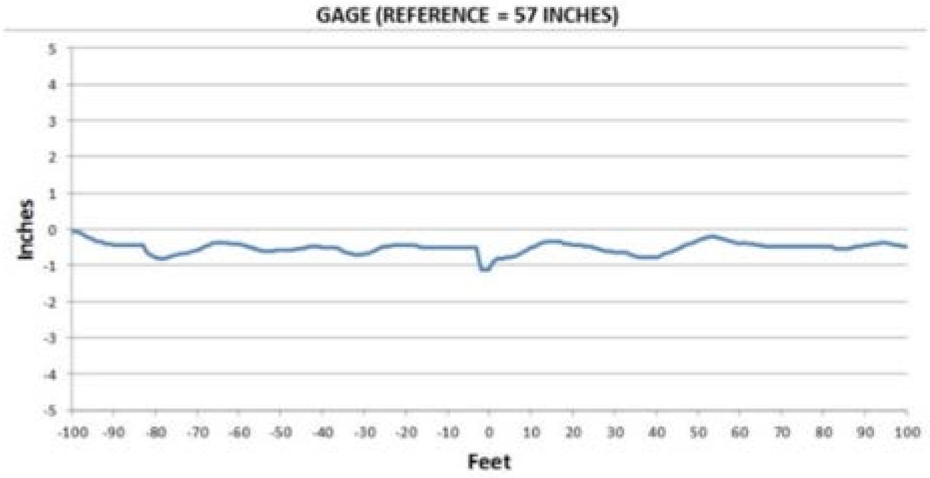
During Stage 1 efforts, ENSCO employed two different methods to identify and remove "false" geometry defects. These methods were based on decades of experience with manned track geometry data collection and years of developing false exception detection routines in autonomous track assessment systems such as ARMS.

The first method employed a human-trained decision model designed to recognize patterns associated with the actual experiences of human data editors and apply those patterns to potential measured defects. Edited data from thousands of survey miles was used to "teach" the program how to filter out false exceptions. The second method relied on a computational signature analysis algorithm that analyzed frequency components of the measured signals to identify those cases that exhibited higher-frequency components that would cause the reported geometry measurement to be questioned.

After initial development and several refinements, this two-pronged approach to exception editing proved effective at removing instances in which data appeared to correspond with false geometry defects. Illustrations of the types of false exceptions identified by the approach described above are shown in Figure 57. In Figure 57a, a false crosslevel deviation was automatically identified based on its unrealistic signature. In Figure 57b, a narrow gage exception was automatically identified based on the presence of a constant gage measurement followed by a relatively large change in gage over a short distance.



(a) False Crosslevel Geometry Exception



(b) False Gage Geometry Exception

Figure 57: Examples of False Geometry Exceptions Automatically Identified

This approach proved capable of filtering out exceptions attributable to signals suffering from dirty measurement optics, gage conditions found at diamond frogs and turnouts, as well as profile irregularities observed in crossovers. However, more improvements were required.

Assessments of exception filter effectiveness conducted in the spring of 2009 indicated that:

- In general, 25 percent of detected exceptions reported by the system were valid track events; the filtering approach employed at the time was not effective.

- A majority of false exceptions were associated with limiting speed, crosslevel, and alignment deviations. Discrepancies were attributed to inaccurate curve transition detection (i.e., proper determination of when the vehicle had entered a curve) and sensor anomalies (gage spikes, accelerometer saturation) that occasionally affected data quality.

ENSCO adjusted the system to address these deficiencies. Developers moved from a multi-phase approach to exception filtering in which it detected waveforms that were compared to a series of thresholds to eliminate obvious false exceptions with the remaining exceptions analyzed using a Support Vector Machine classifier. The classifier was trained using historical exception data to replicate the performance of operators trained for manned inspection car surveys. Although this approach provided some improvements, the rate of false exceptions being passed through as valid was still unacceptable.

In 2010, a new “decision tree” type approach was used in which each exception was assessed with algorithms that employed independent rules developed, in part, using data gathered during manned survey operations. These rules employed considerations of peak-to-peak values, noise levels and frequency components of individual waveforms associated with the detected exceptions. This approach yielded acceptable results. Comparisons of both a manual and automatic review of geometry defects detected over the Auto Train route indicated agreement with both accepted and rejected geometry exceptions in over 90 percent of the cases.

Although results of the automated filtering approach at the end of Stage 1 were encouraging, FRA and ENSCO did not observe the same level of success in evaluations conducted on routes throughout the country during Stage 2 and 3. In the analysis of ATGMS results compared to those collected with the manned system onboard DOTX 220, true exceptions missed by ATGMS were largely impacted by issues associated with track class determination as well as the exception validation logic used with ATGMS as compared to crew observations of track features. Consideration of these results following subsequent efforts in Stages 2 and 3 indicates that the relative success of the 2010 exception filtering method was likely attributable to the training data taken from the Auto Train route that was used to establish algorithms.

For applications in which ATGMS would be employed over captured routes on a regular basis, automated exception filters developed in the later efforts of Stage 1 effectively minimize false exceptions. For a wider range of operating conditions, or for the purposes of enforcement of safety standards, the use of the Remote Editor Console can provide additional quality measures. The Remote Editor Console allows FRA to employ procedures similar to those that meet the requirements of the International Standards Organization (ISO) 17025 certification employed in its manned survey operations, thereby, ensuring the quality of results reported to survey stakeholders.

4.2 Track Degradation Analysis

FRA recognized the need for a track degradation analysis tool to take advantage of increased inspection frequencies facilitated by ATGMS. A tool of this nature would automatically process data collected during multiple surveys on the same track to determine degrading track segment conditions, allowing stakeholders to identify track locations that require preventative maintenance. The approach is intended to efficiently process archived surveys from ATGMS or manned systems to estimate the rate of degradation.

ENSCO prepared a general phased approach to implementing track degradation analysis conducive to track geometry parameters as well as other data collected by FRA’s RD&T. To minimize development time, a time series-based approach in which linear or non-linear extrapolation methods to determine degradation rates was recommended. As research in degradation models advances, the methods proposed could be shifted towards the use of more in-depth models that include the influences of various contributing factors.

The general track degradation analysis approach relied on the following steps that are fundamental to such analyses:

- Track Segmentation – Dividing the track into segments small enough to ensure uniform behavior throughout the segment
- Data Alignment – Align geo-referenced measurements from multiple surveys while ensuring that data of questionable quality is not included in the analysis
- Degradation Indices – Develop indices to monitor aggregate changes in measurements within each segment
- Degradation Forecasting – Establish models for trending and forecasting magnitudes of change as well as rates of change of track parameters within each segment. Given sufficient frequency of measurements, degradation modeling would be used to identify locations of concern prior to those locations reaching dangerous conditions

ENSCO recommended early implementation in the form of an offline tool utilizing track geometry data stored within the ATGMS archive. As the tool advances and routes are continually surveyed over time, the degradation analysis could be migrated to a near real-time application that allows analysis and identification of areas of concern as data is received on ATGMS servers.

4.3 Track Determination

The precise location of ATGMS on a given rail network, particularly in situations where multiple tracks run very close to one another, was essential for viability. Track determination is critical to find and correct geometry exception conditions efficiently. Multiple surveys can be properly aligned for long-term monitoring and analysis.

A survey of viable methods of track determination was prepared during Stage 2 [2]. Of the methods documented in the survey, an approach referred to as GPS Map Matching was recommended as the most appropriate means to reach FRA objectives. The method entailed matching the GPS location reported by ATGMS to dynamically segmented base maps that contain locations and designations of individual tracks, MP locations and track class information. An approach to creating these maps was described, but it was noted that detailed information from the railroads is necessary for initial development. Assuming this information will be available in the future, particularly given the advent of Positive Train Control (PTC), this approach represents the greatest chance for long-term success.

Given that this detailed track information is not readily available to FRA, individual track designation is accomplished through indications of track changes within the track geometry data (as evidenced by short curvatures near turnouts) coupled with information available to users of the Remote Editor Console such as track tables and satellite imagery.

5. Conclusion

FRA's RD&T has successfully demonstrated the use of autonomous geometry measurement technology to collect and distribute continuous track geometry data accurately and reliably while in standard revenue service. This has been demonstrated on a variety of vehicles operated in passenger service on a wide range of track conditions, as well as the demonstration of ATGMS in standard freight service for extended operations.

Demonstrations conducted have exhibited the benefits of using ATGMS in regular operations. FRA's RRS has relied on its approach to remote track geometry inspection since 2013. Lessons from FRA's development efforts and their use in track condition monitoring can serve as important guides for the entire rail industry as various forms of autonomous track inspection are adopted. Based on FRA's experience, operations employing staffed inspection vehicles can survey close to 20,000 miles of Class I mainline track over the course of a year. Employing autonomous track inspection equipment on revenue service equipment in passenger service resulted in approximately twice as much track being surveyed in half the time.

As a result of ATGMS technology, FRA has experienced a significant operational cost savings. Based on analysis of costs associated with passenger route assessments conducted in 2013, it is reasonable to expect a 30 to 50 percent reduction in survey costs per mile when compared to the costs of more traditional inspection approaches. These savings are likely to increase as optimized inspection strategies are followed. The transition of this technology to routine assessments conducted as part of FRA's ATIP in 2013 showed that increased inspection coverage and frequency can be achieved with virtually no negative impact on revenue service operations.

Automated exception filters developed in the later efforts of Stage 1 appear sufficient to minimize false geometry defects, especially in captive routes. For a wider range of operating conditions, the use of the Remote Editor Console can provide additional quality control measures. The Remote Editor Console allows FRA to employ well-established procedures similar to those employed in its manned survey operations, thereby, ensuring the quality of the survey results.

As with many technological advances, additional benefits can be realized through continued research and development. FRA and ENSCO have identified several technology areas for further improvement:

- *Autonomous Instrumentation Check and Calibration* - Experience has shown that the equipment employed by FRA has produced reliable data in a very stable fashion. The autonomous nature of this technology will only be enhanced with the development of reliable automatic, self-calibrating systems to minimize the need for manual instrumentation check and calibration activities.
- *Data Management* - Autonomous inspection technology offers many benefits to the railroad community, including high inspection frequencies and the resulting increase in data availability for improved forecasting and trend analysis. This approach to inspection also offers near instantaneous availability of data. This increase in data brings with it several challenges, including issues with handling the increased volume of data resulting from higher inspection frequencies, the creation of useful information and the manner in

which information collected with the system will be integrated into on-going inspection practices.

- *Track Class and Track Determination* - Accurate identification of individual tracks and determination of class of track are critical aspects of ATGMS operation as these directly affect the validity and location of detected geometry exceptions. As more detailed asset information becomes available through initiatives such as PTC implementation, methods to use such information to maximize accuracy of location determination and operating limits will need to be integrated into autonomous inspection systems' infrastructure. Until these capabilities are well-established, measures such as the Remote Editor Console or other approaches can address these needs.

These advances are likely to accelerate the adoption of this technology throughout the rail industry. As FRA's efforts to enhance conditional awareness using autonomous inspection systems continues, industry maintenance practices could become more preventative in nature, leading to an improvement in overall rail safety.

6. References

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2. Carr, G., Payne, J., Saadat, S., and Stuart, C. (2014, September 28–October 1). “Development and Use of FRA Autonomous Track Geometry Measurement System Technology.” AREMA 2014 Annual Conference and Exposition. Chicago, IL.
3. Judge, T. (2004, September). “How Does Your Track Measure Up.” *Railway Age, 205*(9), 77–80. New York, NY.

Appendix A – Geometry Results Comparison – DOTX221(ATGMS) and DOTX220(TGMS)

Comparison of DOTX221 ATGMS and DOTX220 TGMS Geometry Exceptions and Foot-by-Foot Geometry Summary Report

Customer Contract Number: DTFR53-10-D-00002, Task Order 9
ENSCO Project Number: 3670.09

Prepared for:
Federal Railroad Administration
Office of Research, Development and Technology
1200 New Jersey Avenue SE
Washington, DC 20590

Prepared by:
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	Senior Staff Engineer	*Date*
Approved by (Secondary)*		
		Date

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*Secondary Approver If Required

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REV	DESCRIPTION	DATE	REV. BY	ECN NO.
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Executive Summary

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology has undertaken a multi-phase research program focused on the development and advancement of autonomous track geometry measurement systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. Routine collection of track geometry measurements using autonomous, un-manned systems provides many advantages over single purpose, manned systems such as uninterrupted main line track operation and increased inspection frequency allowing for timely detection and monitoring of track locations with safety critical or degradation issues.

The first stage of FRA's development centered on the creation of the basic elements of a ruggedized pilot ATGMS. The second stage of development focused on use and improvement of the technology under revenue service conditions to demonstrate ATGMS accuracy and increase the autonomy of operation of the system. Major accomplishments within this stage, supported under Task Order 9 of FRA's Contract DTFR53-10-D-00002, included the evaluation of a truck-mounted ATGMS installed on FRA's DOTX221 while operated in consist with the FRA Automated Track Inspection Program's (ATIP) DOTX220 manned track geometry inspection vehicle over Amtrak passenger routes between September 2011 and June 2013.

This report documents the performance of the ATGMS as compared to the manned track geometry measurement system during surveys conducted throughout the United States between March and June 2012. Exceptions to track geometry limits defined in the FRA's Track Safety Standards produced by the two systems were compared to each other. Results of this comparison are presented in Section 2. Differences between exceptions produced by the two systems are attributed to seven specific causes. More than half of the observed differences between geometry exceptions produced by the two systems are attributed to class of track determination, which primarily affected ATGMS geometry exception reporting. Differences in geometry measurements from the two systems, particularly in profile and crosslevel, is the second leading cause of differences between geometry exceptions produced by the two systems.

More than 314,000 feet of track geometry data collected by the unmanned and manned systems were compared on a foot-by-foot basis, while areas for comparison were selected based on locations with track geometry exceptions as reported by the manned system aboard DOTX220. Differences in gage, profile, alignment, crosslevel, and curvature measurements collected by the two systems were compared with differences used by FRA to assess overall agreement between multiple measurement systems. Results of this analysis, presented in Section 3, show that the mean difference and standard deviation for crosslevel as well as the mean difference for curvature exceed the multiple system repeatability thresholds. Mean differences and standard deviations for all other measurement parameters meet multiple vehicle repeatability thresholds.

Results of the comparison of the manned and unmanned systems, as well as recommended improvements to FRA's ATGMS, are summarized in Section 4. Analysis presented in this report shows that improving class of track determination used with ATGMS and automated geometry exception editing will improve ATGMS performance to a level approaching that of manned geometry inspection systems.

7. Introduction

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology has undertaken a multi-phase research program focused on the development and advancement of autonomous track geometry measurement systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. Routine collection of track geometry measurements using autonomous, un-manned systems provides many advantages over single purpose, manned systems such as uninterrupted main line track operation and increased inspection frequency allowing for timely detection and monitoring of track locations with safety critical or degradation issues.

The first stage centered on the creation of the basic elements of a ruggedized pilot ATGMS using commercial, off-the-shelf equipment to facilitate early development and evaluation. Emphasis was placed on cellular communication and data transmission, location information tagging, and geometry data and exception processing. The Data Collection module was configured to measure track geometry, analyze the measurements for any locations exceeding limits to the FRA Track Safety Standards and transmit "exception reports" to the server for storage and transmission to survey stakeholders. Automated filters employing a variety of statistics-based algorithms and logic rules were used to identify and eliminate "false" exceptions. Between January 2008 and March 2011 the pilot ATGMS was operated on Amtrak's 39000, a Superliner II railcar, during revenue service operations within Amtrak's Auto Train service that runs between Lorton, VA, and Sanford, FL, over CSX Transportation track. During that time ATGMS surveyed almost 460,000 miles of track, an average of approximately 153,000 miles per year. This extensive testing allowed identification of system problems and limitations, facilitating design modifications that moved ATGMS technology towards increased robustness and reliability.

Following the initial stage of development, the truck-mounted ATGMS was removed from Amtrak's 39000 and moved to FRA's DOTX221, a sleeper-lounge car, for use in Stage 2 development. The second stage of development focused on use and improvement of the technology under simulated revenue operations to demonstrate ATGMS accuracy and increase the autonomy of operation of the system. Major accomplishments within this stage, supported under Task Order 9 of FRA's Contract DTFR53-10-D-00002, included the evaluation of the ATGMS on FRA's DOTX221 while operated in consist with the FRA ATIP's DOTX220 manned track geometry inspection vehicle over Amtrak passenger routes between September 2011 and June 2013 referred to as the Amtrak Assessment program. Please note that for simplicity, hereafter FRA's ATGMS on DOTX221 and FRA's manned geometry inspection system on DOTX220 operated by ATIP personnel are referred to as ATGMS and ATIP, respectively.

This report documents the performance of the ATGMS installed on DOTX221 as compared to the manned track geometry measurement system installed on DOTX220 during Amtrak assessment surveys conducted between March and June 2012 in which the two cars were adjacent to each other within the survey consist during operations over approximately 19,000 track miles. The March 2012 Amtrak Assessment consisted of 16 one-way trips as indicated in Table A9.

Table A9: March 2012 Amtrak Assessment Survey

Trip	Origin	Destination	Miles	Start Date	End Date
1	Washington, DC	New Orleans, LA	1,155	03/29/2012	03/30/2012
2	New Orleans, LA	Los Angeles, CA	1,939	04/02/2012	04/04/2012
3	Los Angeles, CA	Oakland, CA	468	04/06/2012	04/06/2012
4	Oakland, CA	Los Angeles, CA	468	04/06/2012	04/06/2012
5	Los Angeles, CA	Chicago, IL	2,222	04/09/2012	04/11/2012
6	Chicago, IL	New Orleans, LA	918	04/23/2012	04/24/2012
7	New Orleans, LA	San Antonio, TX	575	04/25/2012	04/25/2012
8	San Antonio, TX	Chicago, IL	1,305	04/30/2012	05/01/2012
9	Chicago, IL	Washington, DC	919	05/03/2012	05/04/2012
10	Washington, DC	Miami, FL	1,288	05/07/2012	05/08/2012
11	Miami, FL	Washington, DC	930	05/10/2012	05/10/2012
12	Washington, DC	Chicago, IL	777	05/21/2012	05/22/2012
13	Chicago, IL	Oakland, CA	1,791	05/23/2012	05/24/2012
14	Oakland, CA	Seattle, WA	916	06/01/2012	06/01/2012
15	Seattle, WA	Chicago, IL	2,203	06/04/2012	06/06/2012
16	Chicago, IL	Boston, MA	1,020	06/07/2012	06/07/2012
		Total	**18,894**		

To characterize the performance of the ATGMS, the following comparisons were performed:

- Exceptions to the track geometry limits specified in the FRA Track Safety Standards detected by each system. Geometry exceptions reported by FRA's manned geometry inspection system on DOTX220 were considered as "ground truth" for this analysis;
- Foot-by-foot track geometry data collected by the unmanned and manned systems over more than 314,000 non-consecutive feet of the survey. Areas for comparison were selected based on locations with track geometry exceptions as reported by the manned system aboard DOTX220. Differences in gage, profile, alignment, crosslevel, and curvature measurements collected by the two systems were compared established thresholds used by FRA to assess overall agreement between multiple measurement systems.

A similar analysis was conducted to assess ATGMS using survey data collected by both ATGMS and the manned geometry system aboard DOTX220 during Amtrak Assessments initiated in August 2011; results of this initial comparison were used to identify and address technical/operational issues with the ATGMS.

For the analysis documented in this report, data from Trips 1 and 16 were removed from comparisons of exceptions and foot-by-foot geometry data due to ATGMS data quality issues during Trip 1 and missing ATIP location information (GPS latitude and longitude) during Trip 16. Therefore, only 16,419 track miles of data collected between April 2, 2012, and June 7, 2012, was used for the purpose of analysis presented in this report.

When comparing results provided by ATGMS and manned geometry measurement systems it is important to take into account their operational differences. In particular:

- Manned geometry measurement systems are able to utilize up-to-date posted class of track when ATIP crews edit geometry exceptions. ATGMS, at its current stage of development, relies on vehicle speed to infer class of track to identify geometry exceptions. Therefore, ATGMS is prone to identify a lower class of track based on vehicle speed in many situations than the crew would, creating a significant source for discrepancies in exception detection.
- Differences in vehicles weights and system calibrations result in slight differences in foot-by-foot geometry measurements, resulting in one system reporting an exception while the other does not.
- The automated exception editor employed within ATGMS is designed to review geometry exceptions and accept or reject events as "true" exceptions based on a set of mathematical rules. The ATIP manned geometry review process takes advantage of the operator's years of experience and their ability to observe both track and environmental conditions when deciding if an event is a "true" exception or not.

Results of the exception-based and foot-by-foot measurement-based analyses are presented in Sections 2 and 3 of the final report. Section 4 provides a summary of results and recommendations based on these analyzed.

8. Track Geometry Exception Analysis Results

A total of 1,193 geometry exceptions were reported by the ATIP manned inspection vehicle during Trips 2 through 15 of Table A9. As summarized in Table A10, only 60 reported ATGMS geometry exceptions matched those reported by the ATIP manned system. The mismatched geometry exceptions include 148 geometry exceptions detected but either deleted or not reviewed by the automated exception filters employed by ATGMS and 985 geometry exceptions reported by ATIP manned system but not detected by ATGMS.

Table A10: ATGMS Generated Geometry Exceptions Versus ATIP Reported Geometry Exceptions

		ATGMS			
		Detected and Reported	Detected but Deleted or not-reviewed	Not Detected	**Total ATIP Reported Geometry Exceptions**
ATIP	Detected and Reported	60	148	985	**1,193**

🟩 **Matched geometry exceptions – Detected and Reported by both systems**

🟨 **Mismatched geometry exceptions – Detected by both systems but deleted or not reviewed by ATGMS**

🟥 **Mismatched geometry exceptions - ATIP reported geometry exceptions not detected by ATGMS**

At the first glance, results shown in Table A10 indicate that ATGMS performed poorly and only matched 5 percent of the ATIP-reported geometry exceptions but a closer look at the underlying causes indicates that ATGMS performed reasonably well given its mode of operation.

The Pareto chart in Figure A58 ranks the identified causes of 1,133 (148 plus 985) mismatched geometry exceptions based on degree to which they contribute to differences between the two systems; a "cut-off" corresponding to 80 percent of the total number of events illustrated in the chart is provided for reference. The color scheme used in Figure A58 matches the color scheme used in Table A10. Dark/red columns represent the 985 ATIP-reported geometry exceptions not detected by ATGMS and medium shade/amber columns represent the 148 ATIP geometry exceptions not reported by ATGMS. These were detected but either deleted or not reviewed by the ATGMS automated exception editor.

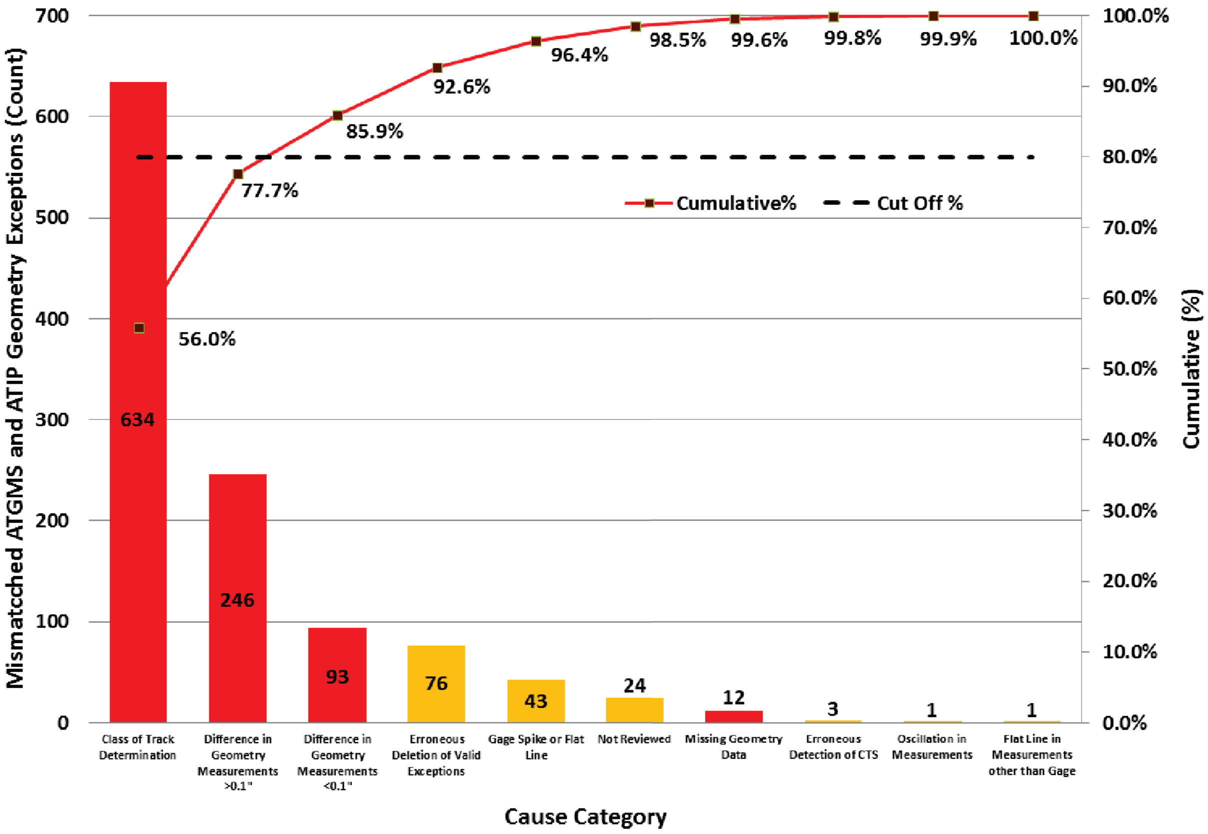

Figure A58: Distribution of Mismatched Geometry Exceptions into Categories of Causes

The following sections provide additional details into these two high-level issues.

8.1 Exceptions not Detected by ATGMS

Consideration of the distribution of 985 ATIP-reported geometry exceptions not reported by ATGMS by different cause categories in Figure A58 shows the following:

- Of the 985 ATIP-reported geometry exceptions not detected by ATGMS, 634 were caused by ATGMS erroneous class of track determination based on the vehicle's speed. At the time of the surveys considered in this report, track class is established based on the speed of the vehicle at any given moment in time. Determination of track class represents an area in which improvements could be realized through a number of different measures including manual review and correction or detailed, up-to-date geo-referenced track class designations that could be provided by individual railroads.
- In addition, 339 out of 985 ATIP reported geometry exceptions not detected by ATGMS were caused by differences in geometry measurements between the ATIP manned system and ATGMS attributed to differences in vehicle weights and minor system differences such as offsets. DOTX220, on which the manned system is located, weighs approximately 212,000 lbs with a fairly even weight distribution from end to end. DOTX221, upon which the ATGMS is installed, weighs close to 155,000 lbs with the vehicle being approximately 12,000 lbs heavier on the B-end where the track geometry measurement beam is mounted.

- The remaining 12 out of 985 ATIP-reported geometry exceptions not detected by ATGMS are due to missing ATGMS geometry data. This occasionally occurs when ATGMS is recovering from a system issue that requires system restart while the test consist continues to survey.

Once causes for mismatched geometry exceptions are identified, their effect on different types of reported geometry exceptions can be identified. Listed in Table A11 are the 985 ATIP-reported geometry exceptions not detected by ATGMS distributed into 11 geometry exception types and the 4 cause categories previously identified in Figure A58. As indicated by the numbers in Table A11 the erroneous track class determination by ATGMS mostly affected crosslevel and 62-foot cord alignment and profile measurements, differences in geometry measurements being more than 0.1 inches mostly affected crosslevel and 62-foot cord profile measurements, and differences in geometry measurements less than 0.1 inches mostly affected narrow gage measurement.

Table A11: Distribution of ATIP-Reported Geometry Exceptions Not Detected By ATGMS By Exception Type

		Cause Category				
		Not Detected	**Class of Track Determination**	**Difference in Geometry Measurement > 0.1 inches**	**Difference in Geometry Measurement < 0.1 inches**	**Missing Geometry Data**
Geometry Exception Type	**Crosslevel**	**176**	114	49	7	6
	Gage Narrow	**50**	0	3	46	1
	Gage Wide	**19**	11	2	6	0
	L Align 31’	**8**	7	0	1	0
	L Align 62’	**135**	123	5	6	1
	L Prof 62’	**224**	120	96	7	1
	R Align 31’	**11**	10	0	1	0
	R Align 62’	**116**	102	8	6	0
	R Prof 62’	**169**	108	55	6	0
	Warp >6”	**0**	0	0	0	0
	Warp 62’	**77**	39	28	7	3
	TOTAL	**985**	**634**	**246**	**93**	**12**

8.2 Exceptions Not Reported by ATGMS

Consideration of the distribution of 148 ATIP-reported geometry exceptions that were detected but deleted by the ATGMS automated exception editor in Figure A58 shows that of the 148 geometry exceptions:

- Seventy-six were incorrectly deleted by ATGMS automated exception filters. A review of foot-by-foot geometry measurements associated with these exceptions indicated that they were valid exceptions.
- Forty-three were deleted because ATGMS automated exception filters detected spikes and flat lines in the foot-by-foot gage measurement associated with these exceptions. Spikes and flat lines could be caused by factors such as direct sun glare or reflections from the ballast.
- Twenty-four were not reviewed by ATGMS automated exception filters. An exception may not have been reviewed if:
    1. Associated foot-by-foot geometry measurements were not available when automated exception filters queried the ATGMS database for the relevant data. This situation occurred when large amount of data was transferred to the servers causing delays between when an exception was detected and when associated foot-by-foot geometry measurements were became available in ATGMS database.

2. ATGMS automated exception filters could not classify the exception into any one of the pre-defined exception types.
3. ATGMS automated exception filters detected unexpected changes in foot-by-foot geometry measurements indicating missing data, bad data, or errors in calculations.
    - Three were deleted due to erroneous detection of curves and spirals as tangent by ATGMS Curve, Tangent, and Spiral (CTS) detection algorithm.
    - One was deleted due to high frequency oscillations in foot-by-foot geometry measurements.
    - One was deleted due to flat line in foot-by-foot geometry measurements other than gage.

Table A12 lists the 148 ATIP geometry exceptions detected but deleted by the ATGMS automated exception editor by the 11 geometry exception types and 6 cause categories previously identified in Figure A58. Erroneous deletion of valid exceptions, spikes and flat lines in gage measurement, and instances when ATGMS automated exception filters did not review exceptions mostly affected 62-foot cord alignment measurements. Erroneous deletion of valid exceptions also affected 62-foot warp measurements. Errors in curvature calculation, i.e. detecting curves and spirals as tangent, only affected the identification of crosslevel exceptions. Oscillations in foot-by-foot geometry measurements and flat lines in geometry measurements other than gage affected one 62-foot cord warp exception and one exception to alignment safety threshold.

Table A12: Distribution of ATIP-Reported Geometry Exceptions Detected but Deleted by ATGMS by Exception Type

		Cause Category						
		Detected but Deleted or Not Reviewed	**Erroneous Deletion of Valid Exceptions**	**Gage Spike or Flat Line**	**Not Reviewed**	**Erroneous Detection of CTS**	**Oscillation in Measurements**	**Flat line in Measurements other than Gage**
Geometry Exception Type	**Crosslevel**	**9**	5	1	0	3	0	0
	Gage Narrow	**1**	0	1	0	0	0	0
	Gage Wide	**5**	4	1	0	0	0	0
	L Align 31'	**1**	0	1	0	0	0	0
	L Align 62'	**49**	20	17	11	0	0	1
	L Prof 62'	**9**	5	4	0	0	0	0
	R Align 31'	**0**	0	0	0	0	0	0
	R Align 62'	**42**	15	14	13	0	0	0
	R Prof 62'	**12**	8	4	0	0	0	0
	Warp >6"	**0**	0	0	0	0	0	0
	Warp 62'	**20**	19	0	0	0	1	0
	TOTAL	**148**	**76**	**43**	**24**	**3**	**1**	**1**

Analysis presented in this report shows that two of the critical factors affecting ATGMS performance is track class determination and the ability of the system to discriminate valid exceptions from false exceptions in a consistently reliable fashion. Following this evaluation, FRA sponsored the development of a web application for remote editing of ATGMS exceptions. With the use of this application, ATGMS generated exceptions are presented to an experienced operator located at a remote site for review and editing. Based on available information such as track charts, timetables and aerial images, the user of the application will be able to provide critical inputs into the proper identification of tracks over which the system is traversing and the establishment of track class.

It is conservatively anticipated that operation of this web application will improve ATGMS track class determination by close to 90 percent, reducing the number of exceptions in this category from 634 to 63 exceptions. In combination with allowing an experienced user to review candidate exceptions prior to transmission to survey stakeholders, these improvements will significantly increase the percentage of ATGMS reported geometry exceptions that would match the reliability of geometry exceptions reported by a manned system.

9. ATGMS and ATIP Foot-by-Foot Geometry Data Comparison

Geometry exceptions are used as markers for retrieving corresponding ATGMS and ATIP foot-by-foot geometry data for comparison. Out of 1,193 ATIP reported geometry exceptions, 798 were used for identifying foot-by-foot geometry measurements for detailed comparison. Three hundred and ninety-five (395) of ATIP reported geometry exceptions were excluded because:

- Three hundred and forty-two represented multiple exceptions types, meaning that various geometry exceptions existed at the same location or within a span of several feet
- Twenty-nine had incomplete or missing foot-by-foot geometry measurements
- Twenty-four were found to be affected by ATGMS malfunctions

The foot-by-foot geometry measurements identified by the remaining 798 geometry exceptions were reviewed to remove measurement outliers and measurements made below cut off speeds of 28 miles per hour (mph) for track geometry calculation. Adjustments were made by removing a small segment of affected measurements from all geometry channels.

This process resulted in more than 314,000 feet of corresponding ATGMS and ATIP foot-by-foot geometry measurements for which resulting statistics were compared against accepted ATIP repeatability thresholds for track geometry data collected from multiple vehicles. These thresholds are presented in Table A13 and statistics resulting from the comparison is presented in Table A14.

Table A13: Repeatability Thresholds for Foot-by-Foot Geometry Data Multiple Vehicles

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Profile (Inches)	0.04419	0.08838
Alignment (Inches)	0.04419	0.17675
Crosslevel (Inches)	0.04419	0.08838
Curvature (Deg/100’)	0.01414	0.21210
Gage (Inches)	0.04419	0.08838

Table A14: Statistics of Difference Between ATGMS and ATIP Foot-by-Foot Geometry Data, March 2012

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Profile (Inches)	-0.0051	*0.0960*
Alignment (Inches)	-0.0001	0.0495
Crosslevel (Inches)	*-0.0711*	*0.1122*
Curvature (Deg/100')	*0.0152*	0.0299
Gage (Inches)	-0.0119	0.0330

Results indicate that mean and standard deviation for crosslevel measurement differences, the mean difference for curvature measurement, and the standard deviation of profile measurement differences exceed the multiple vehicles repeatability thresholds. The mean and standard deviations for all other differences between measurement parameters meet multiple vehicle repeatability thresholds.

10. Conclusions and Recommendations

Over 16,000 miles of track geometry measurements collected between April 2 and June 7 of 2012 by the ATGMS on FRA's DOTX221 while operated in consist with the FRA ATIP's DOTX220 manned track geometry inspection vehicle over Amtrak passenger routes were reviewed to assess agreement between the two measurement systems in terms of exceptions detected as well as foot-by-foot measurements. Exceptions reported by FRA's manned geometry inspection system on DOTX220 were considered as "ground truth" and used to assess performance of the ATGMS. A subset of reported exceptions from DOTX220 manned track geometry inspection vehicle were used to identify areas for comparison of foot-by-foot track geometry data collected by the unmanned and manned systems.

Comparison of foot-by-foot data collected by both systems shows that quality of data collected by ATGMS on FRA's DOTX221 is comparable with the quality of data collected FRA ATIP's DOTX220 manned track geometry inspection vehicle.

DOTX220 manned track geometry inspection vehicle reported 1,193 exceptions. Not all ATGMS generated exceptions matched the 1,193 reported exceptions by DOTX220 manned track geometry inspection vehicle. Mismatched exceptions were reviewed and the following seven categories of causes were identified:

- Class of track determination
- Difference in geometry measurements more than 0.1 inches
- Gage spikes and flat lines
- Difference in geometry measurements less than 0.1 inches
- Erroneous detection of CTS
- Erroneous deletion of valid geometry exceptions
- Flat line in geometry measurements other than gage
- Oscillations in geometry measurements
- Missing geometry data

Review of mismatched exceptions identified ATGMS automated, speed-based logic for class of track determination as the critical factor affecting ATGMS performance. Following assessment of the performance of the ATGMS compared to that of a manned system, a web application for remote editing of ATGMS detected exceptions by an operator was developed to augment ATGMS track class determination logic and automated exception editing until ATGMS technology matures to the point that it can reliably produce results comparable to manned operations. It is anticipated that use of this application will improve ATGMS performance in reporting valid exceptions by 90 percent.

Based on the results of analysis presented in this report, ENSCO has identified the following areas of ATGMS technology for further improvement:

1. **Track Class Determination** – Exceptions to track geometry limits defined in FRA's Track Safety Standards are different for each track class. Track class and associated posted speed are used to apply the proper track geometry limits. Therefore, accurate

determination of track class will improve ATGMS performance in reporting valid exceptions. In 2012, as part of ENSCO's internal research and development efforts, an approach for accurate determination of track number, and by extension track class and posted speed, based on railroad-provided information was developed and tested using limited information provided by a Class I railroad. This approach can be further improved and used to increase ATGMS performance in reporting valid exceptions where railroad-provided information

2. **Automated Geometry Exception Filters** – Automated geometry exception filters inspect validity of an exception by analyzing associated foot-by-foot geometry measurements according to a set of empirically derived limits and signal processing algorithms. Empirically derived limits are based on review of many reported exceptions of the same type by FRA ATIP's manned track geometry inspection vehicles. Signal processing algorithms are designed to detect outliers and anomalies caused by system malfunctions and/or environmental factors such as spikes, flat lines, and high frequency oscillations in geometry measurements. Both empirically derived limits and signal processing algorithms can be further tuned to improve ATGMS performance in reporting valid exceptions. In addition, automated geometry exception filters "exception list" can be expanded to include more exception types to reduce the number of exceptions that could not be classified by the filters, therefore, marked as "not reviewed."
3. **ATGMS Server/Database** – Improving synchronized processing of exceptions and retrieval of associated foot-by-foot geometry measurements will improve ATGMS performance in reporting valid exceptions by reducing the number of exceptions marked by automated exception filters as "not reviewed." Although the occurrence of these situations is relatively infrequent, data flow on ATGMS server/database can be improved to ensure availability of the foot-by-foot geometry data when validity of an exception is evaluated by automated exception filters.

Appendix B – DOTX221 ATGMS Operations Performance Report

DOTX221 ATGMS Operations Performance Report: Summer/Fall 2013 ATIP Amtrak Assessment Survey

Customer Contract Number: DTFR53-10-D-00002
ENSCO Project Number: 3670.09

Prepared for:
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Executive Summary

Using autonomous track geometry measurement systems (ATGMS) for routine collection of track geometry data provides many advantages over operating traditional dedicated track inspection vehicles. Inspection data obtained with autonomous systems can be collected more frequently without track time being consumed by dedicated inspection vehicles. The use of autonomous inspection technologies will result in earlier detection of track defects and changes in maintenance practices from reactive to preventative, ultimately reducing the number of track caused derailments throughout the railroad industry. Use of autonomous inspection technology also offers the promise of expanded coverage and lower overall inspection costs over traditional manned survey operations.

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) has undertaken a multi-phase research program in cooperation with FRA's Office of Railroad Safety focused on the development and advancement of ATGMS and related technologies to improve rail safety. Under Task Order 9 of Contract DTFR53-10-D-00002, an ATGMS was installed on FRA's DOTX221 and deployed in consist with FRA's DOTX220 manned inspection car. The two systems were compared as part of FRA's Automated Track Inspection Program (ATIP) surveys conducted over Amtrak passenger routes in 2011 and 2012. This testing demonstrated that the two systems produced data of equal quality. Differences between measured geometry data were within acceptable limits established for geometry measurements from multiple vehicles. Exceptions generated by the ATGMS and the manned system were compared and differences in reporting were attributed to (a) ATGMS speed-based class of track determination logic, (b) difference in geometry measurements from the two systems, (c) ATGMS automated exception validation logic versus crew observation of track features such as switches, and (d) erroneous deletion and/or validation of exceptions on both systems.

Subsequent research efforts focused on developing and implementing a secure web-based application for near real-time review and validation of geometry exceptions as part of FRA's data management and quality assurance processes. Using a web-based application called Remote Editor Desk developed by ENSCO, a reviewer can make necessary adjustments to control parameters such as track number and track class based on the latest information provided by railroads to validate geometry exceptions. The confirmed exceptions can then be sent to a list of designated recipients. Information available to reviewers to facilitate their decision process include detailed maps using a Google Maps^{TM} display of geographical location of the selected data, displays of foot-by-foot track geometry measured in areas of interest and railroad-provided timetables and track charts.

The use of ATGMS in conjunction with Remote Editor Desk was initially evaluated during surveys conducted with DOTX221 in Amtrak revenue service operations between Washington, DC, and Miami, FL, and Washington, DC, and Chicago, IL, between December 2012 and April 2013 to identify issues and develop enhancements. Following these tests, FRA's RD&T conducted a complete evaluation of DOTX221 ATGMS operation during the 2013 ATIP Amtrak Assessment Survey to assess hardware, software, and processes developed with the goal of providing a sustainable inspection system for ATIP survey operations.

This report provides an overview of DOTX221 ATGMS and Remote Editor Desk performance during 2013 ATIP Amtrak Assessment Survey. There were several minor hardware and software issues identified during the test that were addressed or corrected during scheduled maintenance stops. Overall performance of the Remote Editor Desk for information management and quality assurance met FRA expectations. This report summarizes issues with the measurement system and the Remote Editor Desk that were identified during testing; issues addressed during testing are described and those items that require additional remedial action are described. Recommended enhancements to FRA's ATGMS system and Remote Editor Desk are detailed and evaluation of the repeatability of the system over selected track segments are summarized.

11. Introduction

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The 2013 ATIP Amtrak Assessment consisted of 17 one-way trips starting in Washington, DC, on July 29, 2013, and ending in Washington, DC, on September 29, 2013, covering more than 19,000 miles of track as listed in Table B15. Each of these one-way trips is referred to as a "segment" of the assessment for the purpose of reporting issues. In near real-time, as exception data become available in ATGMS database, an operator used the web-based Remote Editor Desk application to correct for actual track class as well as individual track number and to validate individual exceptions and overall track measurement quality by considering foot-by-foot geometry data, system health information and other system data. Confirmed exceptions were sent as Non-Compliance Exception Reports (NCER). Track Assessment Reports (TAR) covering surveyed track within territory of individual railroads were sent out at the end of each survey, when all track exceptions were confirmed by operators. The TARs include a tabular exception list as well as a summary of all confirmed track geometry exceptions for the reported geographical limits. NCERs and TARs were sent to railroad representatives and FRA personnel at the same time.

The scope of this report is to summarize assessment of DOTX221 ATGMS operations (hardware, software, and Remote Editor Desk) during 2013 ATIP Amtrak Assessment. Those issues affecting ATGMS operations on DOTX221 are categorized into ATGMS Sensors, Electrical and Electronics, Mechanical, Data Collection, Data Transfer, and Data Processing; these are presented in Section 2. Section 3 contains Issues affecting Remote Editor Desk operations; these are categorized into User Interface, Editing, and Reporting. Several enhancements to ATGMS software and hardware, and Remote Editor Desk were also identified and presented in Section 4.

As part of the data evaluation process, foot-by-foot geometry data collected consecutively on three selected track segments during the 2013 ATIP assessment were compared to assess overall data stability and repeatability. This evaluation data included two sets of geometry data collected on the same track between Los Angeles, CA, and Oakland, CA, on consecutive days; two sets of geometry data collected forty days apart on the same track between Memphis, TN, and New Orleans, LA; and two sets of geometry data collected nineteen days apart on the same track between Tempe, TX, and San Antonio, TX. Statistics of differences between the respective sets of collected geometry data on these track segments, presented in Section 5, confirmed ATGMS' repeatability throughout the assignment.

Table B15. 2013 ATIP Amtrak Assessment Survey

Train #	Segment				Survey Miles - Actual	Survey Miles - Scheduled	Survey Miles - Missed	Exceptions Generated	Exceptions Reported
	Origin	Destination	Start Date	End Date					
91	Washington DC	Miami, FL	7/29/2013	7/30/2013	0	1,235	1,235	-	-
98	Miami, FL	Washington DC	8/1/2013	8/2/2013	0	1,164	1,164	-	-
19	Washington DC	New Orleans, LA	8/12/2013	8/13/2013	1,150	1,152	2	1325	19
58	New Orleans, LA	Chicago, IL	8/14/2013	8/15/2013	931	934	3	693	30
5	Chicago, IL	Emeryville, CA	8/19/2013	8/21/2013	2,420	2,438	18	5428	122
14	Oakland, CA	Seattle, WA	8/27/2013	8/28/2013	207	913	706	263	119
8	Seattle, WA	Chicago, IL	8/29/2013	8/30/2013	1,893	2,205	312	1513	252
50	Chicago, IL	Washington DC	9/3/2013	9/4/2013	920	922	2	6311	22
29	Washington DC	Chicago, IL	9/6/2013	9/7/2013	778	780	2	1282	40
21	Chicago, IL	San Antonio, TX	9/9/2013	9/10/2013	1,279	1,305	26	2915	419
2	San Antonio, TX	New Orleans, LA	9/13/2013	9/13/2013	538	573	35	95	8
58	New Orleans, LA	Chicago, IL	9/16/2013	9/17/2013	934	934	0	689	43
3	Chicago, IL	Los Angeles, CA	9/18/2013	9/20/2013	1,876	2,265	389	2168	138
14	Los Angeles, CA	Oakland, CA	9/23/2013	9/23/2013	466	464	-	944	10
11	Oakland, CA	Los Angeles, CA	9/24/2013	9/24/2013	468	464	-	782	10

422	Los Angeles, CA	Chicago, IL	9/25/2013	9/28/2013	2,701	2,728	27	4625	412
30	Chicago, IL	Washington DC	9/29/2013	9/29/2013	n/a	n/a	-	-	-

12. Issues and Recommended Actions for ATGMS Operation

Issues affecting DOTX221 ATGMS operations are categorized into ATGMS Sensors, Electrical and Electronics, Mechanical, Data Collection, Data Transfer, and Data Processing and are listed below. A short description of each issue is provided along with information on its relative impact as characterized by the number of one-way trips, or segments, that were affected by the issue, and the associated recommended actions.

12.1 Sensor Components

12.1.1 *Right Profile Accelerometer Cable*

During the survey between Washington, DC, and New Orleans, LA, started on August 12, 2013, the right profile accelerometer cable was hit and damaged by a wayside object. The connector was temporarily repaired in New Orleans and later replaced in Emeryville, CA, following arrival on August 21, 2013.

Impact: Partial Data Loss	**No. of Affected Segments**: 1	**Status:** Remediated
Recommended Actions: Relocate the profile accelerometer boxes to the opposite side of the beam and reroute the cable to provide better protection.		

12.1.2 *ALD Sensor*

The original ALD sensor failed on July 29, 2013 and was replaced on August 9, 2013. The replacement sensor exhibited drift issues and was replaced on August 22, 2013. No further issues were observed.

Impact: Partial Data Loss	**No. of Affected Segments**: 2	**Status:** Remediated
Recommended Actions: No further action required.		

12.1.3 *Right Rail Scanner*

Scanner S/N 14749 was removed due to low laser power in Washington, DC, and replaced with Scanner S/N 6604 on August 9, 2013. Scanner S/N 6604 was removed due to low laser power in Emeryville, CA, following arrival on August 21, 2013 and replaced with Scanner S/N 11567. Scanner 11567 ran without an issue during the rest of the assignment.

Impact: Data Degradation	**No. of Affected Segments**: 5	**Status:** Remediated
Recommended Actions: No further action required.		

12.1.4 *Global Positioning System*

Water in Global Positioning System (GPS) antenna junction box caused slow acquisition; the water was removed and the antenna/cable connectors were cleaned on August 9, 2013, in Washington, DC. Upon reassembly, all enclosure penetrations were resealed. Satellite constellation table was also updated.

<table>
<tr><td>Impact: Location Accuracy</td><td>No. of Affected Segments: 2</td><td>Status: Remediated</td></tr>
<tr><td colspan="3">Recommended Actions: Modify GPS antenna junction box to prevent water accumulation. Update maintenance practices to inspect junction box routinely.</td></tr>
</table>

12.2 Electrical and Electronics Issues

12.2.1 *Gage Computer Central Processing Unit*

Slow processor and increased processing demand overloaded gage computer Central Processing Unit (CPU) creating flat lines in data and large number dropped data packets. The gage CPU was replaced on August 9, 2013, in Washington, DC.

<table>
<tr><td>Impact: Total Data Loss</td><td>No. of Affected Segments: 2</td><td>Status: Remediated</td></tr>
<tr><td colspan="3">Recommended Actions: No further action required</td></tr>
</table>

12.2.2 *Network Hub*

ATGMS network hub lost power prior to arriving in Washington, DC, before Amtrak Assessment operations due to a shorted Laser Protection System (LPS) motor. On July 26, 2013, separated network hub power feed from LPS to prevent network hub drop outs caused by motor short.

<table>
<tr><td>Impact: None</td><td>No. of Affected Segments: 0</td><td>Status: Remediated</td></tr>
<tr><td colspan="3">Recommended Actions: No further action required</td></tr>
</table>

12.2.3 *Reset Board*

Existing reset board does not allow for remote operator to perform a hard system restart. On two occasions during the Amtrak Assessment, the Amtrak train crew needed to be contacted to manually restart the ATGMS due to system lockup. Replacement is recommended to increase system reliability.

<table>
<tr><td>Impact: Total Data Loss</td><td>No. of Affected Segments: 2</td><td>Status: Open</td></tr>
<tr><td colspan="3">Recommended Actions: Replace existing reset board with one that allows for remote system restart.</td></tr>
</table>

12.2.4 *Head-End-Power*

System did not survey following departure from Oakland, CA, on August 27, 2013, because Amtrak Conductor did not power the car before departure.

Impact: Total Data Loss	**No. of Affected Segments**: 1	**Status:** Closed
Recommended Actions: Consider independent power system.		

12.3 Mechanical Issues

12.3.1 *Laser Protection System*

Motor failed on film advance system. Replaced burned motor with a high torque/low speed unit. Temporarily removed right device due to issues with feeder mechanism. Removed clear film due to condensation and dirt accumulation.

Impact: Data Degradation	**No. of Affected Segments**: 8	**Status:** Open
Recommended Actions: Remove film-based laser protection system and implement shrouds over gage measurement system lenses to allow recess to provide mitigation of dirt.		

12.3.2 *Tachometer Mount*

Loose and missing hardware elements were identified during routine inspections and replaced on July 30, 2013, in Miami, FL. A new mounting plate was fabricated to eliminate isolators and installed August 20, 2013, in Chicago, IL.

Impact: Data Degradation	**No. of Affected Segments**: 0	**Status:** Remediated
Recommended Actions: No further action required.		

12.4 Data Collection Issues

12.4.1 *Alert Messages*

When sensor inactivity and out of range messages were enabled, gage sensor and LPS issues caused a flood of Alert Messages. ATGMS architecture is designed with Alert Messages having priority over raw sensor data packets and Status Messages causing raw sensor data packets not leaving the remote unit. Location information is needed in these messages.

Impact: Delayed Data	**No. of Affected Segments**: 1	**Status:** Open
Recommended Actions: Modify software to suppress the number of inactivity/out of range messages in the event of sensor failure.		

12.4.2 *Status Messages*

Power status is not reported correctly because it is generated by both computers, sent to the server, and combined. Status Message reporting was corrected on August 9, 2013.

Impact: Notification Accuracy	**No. of Affected Segments**: 2	**Status:** Remediated
Recommended Actions: No further action required.		

12.4.3 *Computer Reboot*

When ATGMS software restarts due to direction change or when maximum millage for a run ID is reached, corrupt files or overflow conditions are occasionally observed.

Impact: Total Data Loss	**No. of Affected Segments**: 2	**Status:** Open
Recommended Actions: Modify software to detect and correct corrupt files before starting TGMS. Modify software restart process to eliminate need to reboot computer.		

12.5 Data Transfer Issues

12.5.1 *Out-of-Order Data Packets*

Due to latency in cellular communication, some data packets would arrive at ATGMS servers outside the pre-defined anticipated 2-minute time window. The delayed data packets arrive at ATGMS servers out of order and are discarded. The approach was modified to wait until 10 packets subsequent to a missed packet were received before continuing processing. Additional consideration is needed to minimize data loss as a few out–of-order data packets were observed after modifications.

Impact: Total Data Loss	**No. of Affected Segments**: All	**Status:** Open
Recommended Actions: Reconsider approach to data transmission. Elimination of data loss may result in longer delays between remote collection and server processing in some situations.		

12.6 Data Processing Issues

12.6.1 *Location Offset*

A 200-foot offset was observed in location information. A software modification was issued to correct this issue on August 13, 2013.

Impact: Data Accuracy	**No. of Affected Segments**: 3	**Status:** Remediated
Recommended Actions: No further action required.		

12.6.2 *Offset in Profile Mid-Chord Values*

There is a random initialization issue that occasionally causes mid-chord offset (MCO) values for profile measurements to exhibit an offset at the start of a run. The only recovery method is to restart the Track Geometry Measurement System (TGMS) processor on the server.

Impact: Data Accuracy	**No. of Affected Segments**: 2	**Status:** Open
Recommended Actions: Investigate scenarios that exhibit profile DC offset in order to identify processing failure.		

12.6.3 *Server-Based Processor to Database Data Transfer*

On August 19, 2013, geometry exception data was dropped when pushed from the TGMS processor on the server to the ATGMS database. Restarting the TGMS processor resolved the issue. The missing data was later reprocessed without issue.

Impact: Total Data Loss	**No. of Affected Segments**: 1	**Status:** Hold
Recommended Actions: This is a single isolated incident in the 2+ years running the system. No action is recommended unless further recurrence is observed.		

12.6.4 *Milepost Detection*

Over the course of the entire Amtrak Assessment, 703 exceptions were not tagged with MP information; 267 of these were not tagged with GPS location information either. To resolve the issues with no MP identification, permission was given by three Class 1 railroads to use their MP location information. ATIP historical MP location information was also used to identify other locations of interest.

Impact: Partial Data Loss	**No. of Affected Segments**: All	**Status:** Open
Recommended Actions: Reconsider location determination methodology. Limit possible solutions to only railroad segments on the route being traversed.		

12.6.5 *New File on Railroad Change*

Transitioning from one railroad to another during a particular survey's data file, or "run ID", should have created a new run ID with prefix of A, B, C, etc., but this was not consistently achieved. Improvement to railroad determination algorithm is needed in order to efficiently separate data files according to railroad.

Impact: Data Accuracy	**No. of Affected Segments**: All	**Status:** Open
Recommended Actions: Revise railroad determination algorithm to limit possible solutions to only railroad segments on the route being traversed.		

12.6.6 *Incorrect Region Notification*

Whenever GPS information was missing, exceptions were incorrectly assigned to Region 1. The notification table was updated to remove Region 1 personnel for exceptions without GPS on August 16, 2013.

Impact: Data Accuracy	**No. of Affected Segments**: 4	**Status:** Remediated
Recommended Actions: No further action required.		

It is encouraged that all "open" issues and those for which recommended actions are provided be addressed prior to employing the ATGMS in the next scheduled Amtrak Assessment.

13. Issues Affecting Remote Editor Desk Operations

Issues affecting Remote Editor Desk operations are separated into categories corresponding to those impacting User Interface, Editing, and Reporting functions. These issues have been divided into two reporting categories – those resolved during survey operations and outstanding issues as of the end of 2013 ATIP Amtrak Assessment Survey. A short description of each issue resolved during the Amtrak Assessment is provided in Table B16. Outstanding issues with the Remote Editor Desk are presented in Table B17 along with an associated priority for remediation. It should be noted that issues associated with Remote Editor Desk operations did not have a direct impact on data collected by the ATGMS on DOTX221 but did affect the ability of operators to evaluate and report on survey results.

Table B16: Remote Editor Desk Issues Resolved During 2013 Amtrak Assessment Survey

Category	Description
User Interface	• Map didn't show information for subdivisions with the "&" character in their names; • Start/End city fields longer than 32 characters caused error message; • Exception count statistics on bottom of editor screen needed to be corrected; • Track table "submit" pop up window stopped working part way through a geometry file; • Added "Confirmation" pop up window to prevent incorrect exceptions from being sent via NCER; • Utility improperly applied track table when changing track number or class from exception list; • Needed to show space curve channels for runoff exceptions; • Corrected differences between ALD values on Remote Editor Desk and those shown in NCERs;
Editing	• Needed to exclude exceptions and curves without MP/GPS info from Editor; • Corrected issue where exceptions erroneously deleted when posted class raised; • Originally not able to change track number and posted class for exceptions that don't have corresponding track table entries; • Corrected situation when narrow gage exceptions deleted after changing posted class; • Corrected cases where applying the track table doesn't consistently delete exceptions; • Originally unable to change track number if there is no entry in the track table; • Curves that are not modified by operator have default track number assigned as opposed to actual track number – this was remedied;
Reporting	• Excluded exceptions and curves without MP/GPS info from reports; • Trimmed exception type on header of NCER's to eliminate blank space; • NCER strip chart corrected so it did not show cant channels; • Exception not always centered on NCER strip chart; • Application corrected so it sent email rather than TAR reports for run IDs with no exceptions; • File names of TARs and NCERs were not originally consistent with ATIP operations; • Needed ability to change the railroad when creating a report;

Table B17: Outstanding Remote Editor Desk Issues Following 2013 Amtrak Assessment Survey

Priority	Category	Description
High	Editing	Verify track number and position info on Curve records
High	Editing	Correct issue where system deleted exceptions after NCERs were sent
High	Reporting	Need ability to control the range of exceptions for ASCII file export
High	Reporting	Correct issue when NCERs failed to transmit properly
High	Reporting	Ability to define a range of exceptions that spans multiple pages
Medium	User Interface	Adjust turnout detection to improve identification
Medium	User Interface	Add red tick mark on Video Strip Chart to indicate location of exception
Medium	User Interface	Properly update summary numbers with multiple pages of exceptions
Medium	User Interface	Correct issue where application randomly locks out users when in Test Mode
Medium	Reporting	Add note to reports indicating turnouts are not exceptions
Medium	Reporting	Limit speed exceptions should not show “Limiting Class 0” on TARs
Medium	Reporting	Correct situation where the railroad is set to “UNKNOWN” in the subject line of TAR delivery emails when the railroad is not properly identified by exception locations
Low	User Interface	After login page, user must refresh browser to get query dialogue
Low	User Interface	Show ATGMS Units button works only in multi-window mode
Low	Editing	Investigate application lock up while sending NCERs
Low	Reporting	Investigate issue where BNSF internal exception tracking file contained bad information after “NO EXCEPTION” messages were sent

14. Recommended ATGMS Enhancements

Surveying 19,000 miles of track with ATGMS on Amtrak revealed a number of future enhancements that could improve its autonomous operations on DOTX221 or any other vehicle. Enhancements to the hardware and software associated with the measurement system and transfer of its data are provided in Table B18; these should be considered as additional recommendations beyond the correction of issues identified in Section 2. Enhancements to the Remote Editor Desk that will be instrumental in improving the efficiency of data review and reporting are indicated in Table B19.

Table B18: Recommended ATGMS Hardware and Software Enhancements

Priority	Category	Description
High	Hardware	Physically separate ATGMS and TDMS databases by employing an additional server to handle data processing tasks
High	Hardware	Upgrade the cellular modem from 3G to 4G to improve communication rates
Medium	Software	Add ability to export .dt1 files from ATGMS server
Medium	Software	Improvements to remote control/diagnostic tool (dispdbg)
Low	Software	Automate data overlay to self or other ATIP cars
Low	Hardware	Add a set of dedicated calibration tools

Table B19: Recommended Remote Editor Desk Enhancements Following 2013 Amtrak Assessment Survey

Priority	Category	Description
High	User Interface	Show time since last data received on server in header of exception list
High	Editing	Add ability to break run IDs for changing railroads and excessive file lengths on the server rather than the car
High	Editing	Add ability to edit track table in real-time and save/apply (similar to TrackIT® Console)
High	Editing	Remote Editor Desk needs to recheck deleted exceptions when higher track class is reapplied
High	Reporting	Express reported values consistently across all exception types in NCERs, TARs, etc.
Medium	User Interface	Show mileage in the run ID selection list box
Medium	User Interface	Show mileage in header of exception list
Medium	User Interface	Strip chart navigation buttons need to be larger and not move between clicks
Medium	Reporting	Need to have capability to run ATIP's Duplicate Exception Reports (DERs) on the ATGMS data
Low	Reporting	Exceptions should have unique ID numbers provided with exception name (BNSF is primary user)
Low	Reporting	Add ability to combine run IDs for "No Exception" messages sent to railroads

15. Analysis of Collected Foot-by-Foot Geometry

Foot-by-foot geometry data collected on three selected track segments at different times during the 2013 ATIP Amtrak Assessment Survey were analyzed to evaluate ATGMS’ repeatability and Remote Editor Desk’s utilization and operators’ performances throughout the assignment. Results of this analysis are presented in the following sections.

Data used to analyze foot-by-foot geometry measurements included two sets of geometry data collected on the same track between Los Angeles, CA, and Oakland, CA, on consecutive days; two sets of geometry data collected forty days apart on the same track between Memphis, TN, and New Orleans, LA; and two sets of geometry data collected nineteen days apart on the same track between Tempe, TX, and San Antonio, TX. This comparison, although not a true measure of repeatability, was intended to indicate the general stability of the system.

Foot-by-foot geometry measurements associated with several random locations along each segment on both days were extracted. Invalid data segments were deleted before comparison; these segments included:

- Those in which measurements were made below 30 mph, the cut-off speed for a number of track geometry parameters;
- Areas of flat lines in gage, since gage is used to align two sets of data over the same track.

The remaining foot-by-foot geometry measurements represented a little more than 493,000 feet of track between Los Angeles, CA, and Oakland, CA; over 627,000 feet of track between Memphis, TN, and New Orleans, LA; and close to 277,700 feet of track between Tempe, TX, and San Antonio, TX. Statistics based on the differences between the various sets of aligned track data were compared against accepted ATIP repeatability thresholds for comparing any two data sets over the same track by two different vehicles; these thresholds are presented in Table B20. The summary of the consideration of the various ATGMS data sets are presented in Table B21, Table B22, and Table B23 with Mean Difference and/or Standard Deviation of any geometry parameter exceeding the acceptable repeatability thresholds highlighted in red/italics. Statistics of differences between the respective sets of collected geometry data on these track segments show that ATGMS’ performance is very stable.

Table B20: Repeatability Thresholds for Foot-by-Foot Geometry Data, Multiple Cars

	Multiple Cars	
Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Profile (Inches)	0.04419	0.08838
Alignment (Inches)	0.04419	0.17675
Crosslevel (Inches)	0.04419	0.08838
Curvature (Deg/100')	0.01414	0.21210
Gage (Inches)	0.04419	0.08838

Table B21: Statistics of Difference Between Foot-by-Foot Geometry Measurements Collected Between Los Angeles, CA, and Oakland, CA

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Gage (Inches)	-0.00627	0.02865
Crosslevel (Inches)	*0.05907*	0.05386
Curvature (Deg/100')	-0.00872	0.05733
LProfile31 (Inches)	0.00003	0.03736
RProfile31 (Inches)	0.00005	0.03662
LAlign31 (Inches)	0.00007	0.02970
RAlign31 (Inches)	0.00004	0.03024
LProf62 (Inches)	0.00003	0.03983
RProf62 (Inches)	0.00003	0.03912
LAlign62 (Inches)	0.00004	0.03397
RAlign62 (Inches)	0.00001	0.03383
LProf124 (Inches)	0.00006	0.04260
RProf124 (Inches)	0.00005	0.04175
LAlign124 (Inches)	0.00005	0.05628
RAlign124 (Inches)	-0.00000	0.05616

Table B22: Statistics of Difference Between Foot-by-Foot Geometry Measurements Collected Between Memphis, TN, and New Orleans, LA

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Gage (Inches)	-0.01392	0.03738
Crosslevel (Inches)	*-0.08217*	*0.08456*
Curvature (Deg/100’)	0.00188	0.01800
LProfile31 (Inches)	0.00008	0.04641
RProfile31 (Inches)	0.00006	0.04479
LAlign31 (Inches)	0.00000	0.03413
RAlign31 (Inches)	-0.00003	0.04202
LProf62 (Inches)	0.00008	0.05457
RProf62 (Inches)	0.00009	0.05252
LAlign62 (Inches)	0.00001	0.04373
RAlign62 (Inches)	0.00000	0.05125
LProf124 (Inches)	0.00009	*0.07716*
RProf124 (Inches)	0.00012	*0.07665*
LAlign124 (Inches)	0.00003	0.07184
RAlign124 (Inches)	0.00006	0.07670

Table B23: Statistics of Difference Between Foot-by-Foot Geometry Measurements Collected Between Tempe, TX, and San Antonio, TX

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Gage (Inches)	0.00719	*0.02469*
Crosslevel (Inches)	0.02910	*0.07908*
Curvature (Deg/100')	-0.00879	0.03530
LProfile31 (Inches)	0.00001	0.04956
RProfile31 (Inches)	0.00000	0.05120
LAlign31 (Inches)	0.00005	*0.03250*
RAlign31 (Inches)	0.00003	0.03184
LProf62 (Inches)	-0.00004	0.06698
RProf62 (Inches)	-0.00003	0.06929
LAlign62 (Inches)	0.00006	0.05830
RAlign62 (Inches)	0.00004	0.05723
LProf124 (Inches)	0.00004	*0.08745*
RProf124 (Inches)	0.00009	*0.08762*
LAlign124 (Inches)	0.00024	0.08570
RAlign124 (Inches)	0.00018	0.08544

16. Conclusions

The focus of FRA's RD&T during 2013 ATIP operations was the evaluation of ATGMS technology and operational procedures with the goal of providing a sustainable track inspection system for FRA's Office of Safety ATIP operations.

FRA Office of Railroad Safety's use of ATGMS without an accompanying manned survey car started in Washington, DC, on July 29, 2013, and ended in Washington, DC, on September 29, 2013, covering more than 19,000 miles of track. In near real-time, as track geometry data was recorded, transmitted and processed for exceptions to established thresholds, a reviewer used the web-based application to correct for actual track class as well as individual track number and to validate individual exceptions in addition to overall track measurement quality by considering foot-by-foot geometry data, system health information and other system data. A review of foot-by-foot geometry measurements collected on three selected track segments at different times during 2013 ATIP operation provided a general sense of ATGMS' repeatability and stable performance.

During the survey, the ATGMS and Remote Editor Desk operations were affected by a number of hardware and software issues. ATGMS operations were reviewed and issues affecting the system were categorized into Sensors, Electrical and Electronics, Mechanical, Data Collection, Data Transfer, and Data Processing. A review of Remote Editor Desk operations identified issues that were categorized into User Interface, Editing, and Reporting. A short description of each issue was provided as well as information on final status of the issue, its impact, and any additional recommended actions. Evaluation of the survey also highlighted a series of hardware and software enhancements that will improve ATGMS reliability as well as performance of Remote Editor Desk operations.

FRA's vision is to improve track safety and maintenance practices by enhancing conditional awareness using autonomous inspection systems. The interim result of FRA's five-stage ATGMS research program is a modular, unattended geometry measurement system that can be deployed on standard rail equipment to collect and distribute accurate track geometry data while running in a standard revenue train. FRA has employed this technology during Office of Railroad Safety evaluations and demonstrated that is a viable approach to safety assessment. Further improvement to this technology, as described in this report, will result in improved operations, efficiency and reliability benefiting not only for FRA but the industry as a whole.

Appendix C – Comparison of Track Geometry Measured with a Carbody-Mounted ATGMS and Amtrak's 10002

Comparison of Track Geometry Measured with a Carbody-Mounted ATGMS and Amtrak's 10002 Summary Report

Customer Contract Number: DTFR53-10-D-00002, Task 14
ENSCO Project Number: 3670.14

Prepared for:
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17. Executive Summary

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology has undertaken a multi-phase research program focused on the development and advancement of autonomous track geometry measurement systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. Routine collection of track geometry measurements using autonomous, un-manned systems provides many advantages over single purpose, manned systems such as uninterrupted main line track operation and increased inspection frequency allowing for timely detection and monitoring of track locations with safety critical or degradation issues.

Basic elements of a ruggedized pilot ATGMS were developed under the first stage of FRA's development of the technology. The second stage focused on use and improvement of the technology under simulated revenue operations over Amtrak passenger routes to demonstrate ATGMS accuracy and increase the autonomy of operation of the system. The third stage was centered on development and evaluation of a carbody-mounted ATGMS. The objective of the carbody-mounted system's design was to minimize interference with truck and wheel set maintenance activities, better protect the measurement platform from flying debris and mud, and allow for installation of ATGMS on a wide range of vehicle designs with a lower installation and maintenance cost.

The major accomplishments for this stage, supported under Task Order 14 of FRA's Contract DTFR53-10-D-00002, included demonstration of the new sensor and processing algorithms to account for new techniques to measure track geometry from a location further away from the rails. For demonstration and evaluation purposes, a carbody-mounted ATGMS was installed and operated on Amtrak's 82602, an Amfleet I passenger car, in revenue service on the Northeast Corridor (NEC).

This report documents the performance of the carbody-mounted ATGMS as compared to a manned, truck-mounted geometry inspection system installed on Amtrak's survey vehicle designated as 10002 during surveys conducted on NEC between October 2012 and August 2013. Exceptions to track geometry limits defined in FRA's Track Safety Standards produced by the two systems were compared to each other. Results of this comparison are presented in Section 2. Differences between geometry exceptions produced by the two systems are attributed to five categories of causes. More than half of the observed differences between geometry exceptions produced by the two systems are attributed to differences in geometry measurements from the two systems. Class of track determination affected ATGMS geometry exception reporting and was the second leading cause of differences between geometry exceptions generated by the two systems.

More than 31,000 feet of track geometry data collected by the unmanned and manned systems were compared on a foot-by-foot basis; areas for comparison were selected based on locations with track geometry exceptions as reported by the manned system aboard Amtrak's 10002. Differences in gage, profile, alignment, crosslevel, and curvature measurements collected by the two systems were compared with differences used by FRA to assess overall agreement between multiple measurement systems. Results of this analysis, presented in Section 3, show that the mean difference and standard deviation for crosslevel as well as the mean difference for gage exceed the multiple system repeatability. Mean differences and standard deviations for all other measurement parameters meet multiple vehicle repeatability thresholds.

Results of the comparison of the manned and unmanned systems, as well as recommended improvements to FRA’s ATGMS, are summarized in Section 4. Analysis presented in this report shows that improving class of track determination used with ATGMS and automated geometry exception editing will improve ATGMS performance to a level approaching that of manned geometry inspection systems.

18. Introduction

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) has undertaken a multi-phase research program focused on the development and advancement of autonomous track geometry measurement systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. Routine collection of track geometry measurements using autonomous, un-manned systems provides many advantages over single purpose, manned systems such as uninterrupted main line track operation and increased inspection frequency allowing for timely detection and monitoring of track locations with safety critical or degradation issues.

The first stage centered on the creation of the basic elements of a ruggedized pilot ATGMS using commercial, off-the-shelf equipment to facilitate early development and evaluation. Emphasis was placed on cellular communication and data transmission, location information tagging, and geometry data and exception processing. The Data Collection module was configured to measure track geometry, analyze the measurements for any locations exceeding limits to the FRA Track Safety Standards and transmit "exception reports" to the server for storage and transmission to survey stakeholders. Automated filters employing a variety of statistics-based algorithms and logic rules were used to identify and eliminate "false" exceptions. Between January 2008 and March 2011 the pilot ATGMS was operated on Amtrak's 39000, a Superliner II railcar, during revenue service operations within Amtrak's Auto Train service that runs between Lorton, VA, and Sanford, FL, over CSX Transportation track. During that time ATGMS surveyed almost 460,000 miles of track, an average of approximately 153,000 miles per year. This extensive testing allowed identification of system problems and limitations, facilitating design modifications that moved ATGMS technology towards increased robustness and reliability.

Following the initial stage of development, the truck-mounted ATGMS was removed from Amtrak's 39000 and moved to FRA's DOTX221, a sleeper-lounge car, for use in Stage 2 development. The second stage of development focused on use and improvement of the technology under simulated revenue operations to demonstrate ATGMS accuracy and increase the autonomy of operation of the system. Major accomplishments within this stage, supported under FRA funding, included the evaluation of the ATGMS on FRA's DOTX221 while operated in consist with the FRA Automated Track Inspection Program's (ATIP) DOTX220 manned track geometry inspection vehicle over Amtrak passenger routes between September 2011 and June 2013 referred to as the Amtrak assessment program.

To allow for installation of ATGMS on a wide range of vehicle designs, lower installation and maintenance costs as well as minimal interference with truck and wheel set maintenance activities, FRA's RD&T initiated development and evaluation of a carbody-mounted ATGMS. Major accomplishments of this stage of development included demonstration of the new sensor and processing algorithms to account for new techniques to measure track geometry from a location further away from the rails. For demonstration and evaluation purposes, a carbody-mounted ATGMS was installed and operated on Amtrak's 82602, an Amfleet I passenger car, in Amtrak revenue service on the NEC between September 2012 and August 2013, covering more than 55,000 track miles. Its performance was evaluated by comparing its results to that of the truck-mounted track geometry measurement system (TGMS) installed on Amtrak's manned geometry inspection vehicle, 10002, in the following manners:

- Exceptions to the track geometry limits specified in the FRA Track Safety Standards detected by each system. Geometry exceptions reported by the Amtrak's manned geometry inspection system on Amtrak 10002 were considered as "ground truth" for this analysis.
- Foot-by-foot track geometry data collected by the unmanned and manned systems over more than 17,500 non-consecutive feet of the survey. Areas for comparison were selected based on locations with track geometry exceptions as reported by the manned system aboard Amtrak's 10002. Differences in gage, profile, alignment, crosslevel, and curvature measurements collected by the two systems were compared to established thresholds used by FRA to assess overall agreement between multiple measurement systems.

An analysis of this nature was conducted to assess ATGMS using survey data collected by both ATGMS and the manned geometry system aboard Amtrak's 10002 during October 2012; results of this initial comparison were used to identify and address technical/operational issues with the ATGMS. For the analysis documented in this report, 346 out of 914 track miles of data collected on April 2 and 3, 2013, between Washington, DC, and Boston, MA, were used due to intermittent ATGMS operational and data quality issues during this survey.

Please note that for simplicity, hereafter Amtrak's 82602 ATGMS and Amtrak's 10002 are referred to as ATGMS and 10002 respectively.

When comparing results provided by ATGMS and manned geometry measurement systems it is important to take into account their operational differences. In particular:

- Manned geometry measurement systems are able to utilize up-to-date posted class of track when ATIP crews edit geometry exceptions. ATGMS, at its current stage of development, relies on vehicle speed to determine class of track to identify geometry exceptions. Therefore, ATGMS is prone to identify a lower class of track based on vehicle speed in many situations than the crew would, creating a significant source for discrepancies in exception detection.
- Differences in vehicles weights and system calibrations result in slight differences in foot-by-foot geometry measurements, resulting in one system reporting an exception while the other does not.
- The automated exception editor employed within ATGMS is designed to review geometry exceptions and accept or reject events as "true" exceptions based on a set of mathematical rules. The manned geometry review process employed by Amtrak and others takes advantage of the operator's years of experience and their ability to observe both track and environmental conditions when deciding if an event is a "true" exception or not.

Results of the exception-based and foot-by-foot measurement-based analyses are presented in Sections 2 and 3, respectively. Section 4 provides a summary of results and recommendations based on these analyzed.

19. Track Geometry Exception Analysis Results

A total of 63 geometry exceptions were reported by 10002 during the round-trip between Washington, DC, and Boston, MA, on April 2 and 3, 2013. As summarized in Table C24, only 18 geometry exceptions reported by ATGMS matched those reported by the 10002 manned system. The mismatched geometry exceptions include 4 geometry exceptions detected but deleted by the automated exception filters employed by ATGMS and 41 geometry exceptions reported by the 10002 manned system but not detected by ATGMS.

Table C24: ATGMS Generated Geometry Exceptions versus 10002-Reported Geometry Exceptions

		ATGMS			
		Detected and Reported	Detected but Deleted	Not Detected	**Total 10002-Reported Geometry Exceptions**
10002	Detected and Reported	18 (28.6%)	4 (6.3%)	41 (65%)	**63 (100%)**

Matched geometry exceptions – Detected and Reported by both systems

Mismatched geometry exceptions – Detected by both systems but deleted by ATGMS

Mismatched geometry exceptions – 10002-reported geometry exceptions not detected by ATGMS

At the first glance, results shown in Table C24 indicate that ATGMS performed poorly and only matched 28.6 percent of the 10002 reported geometry exceptions but a closer look at the underlying causes indicates that ATGMS performed reasonably well given its mode of operation.

The Pareto chart in Figure C59 ranks the identified causes of 45 (4 plus 41) mismatched geometry exceptions based on degree to which they contribute to differences between the two systems; a "cut-off" corresponding to 80 percent of the total number of events illustrated in the chart is provided for reference. The color scheme used in Figure C59 matches the color scheme used in Table C24. Dark/red columns represent the 41 10002-reported geometry exceptions not detected by ATGMS and medium shade/amber columns represent the 4 geometry exceptions reported by Amtrak's 10002 that were not reported by ATGMS; these were detected but deleted by the ATGMS automated exceptions editor.

The following sections provide additional details into these two high-level issues.

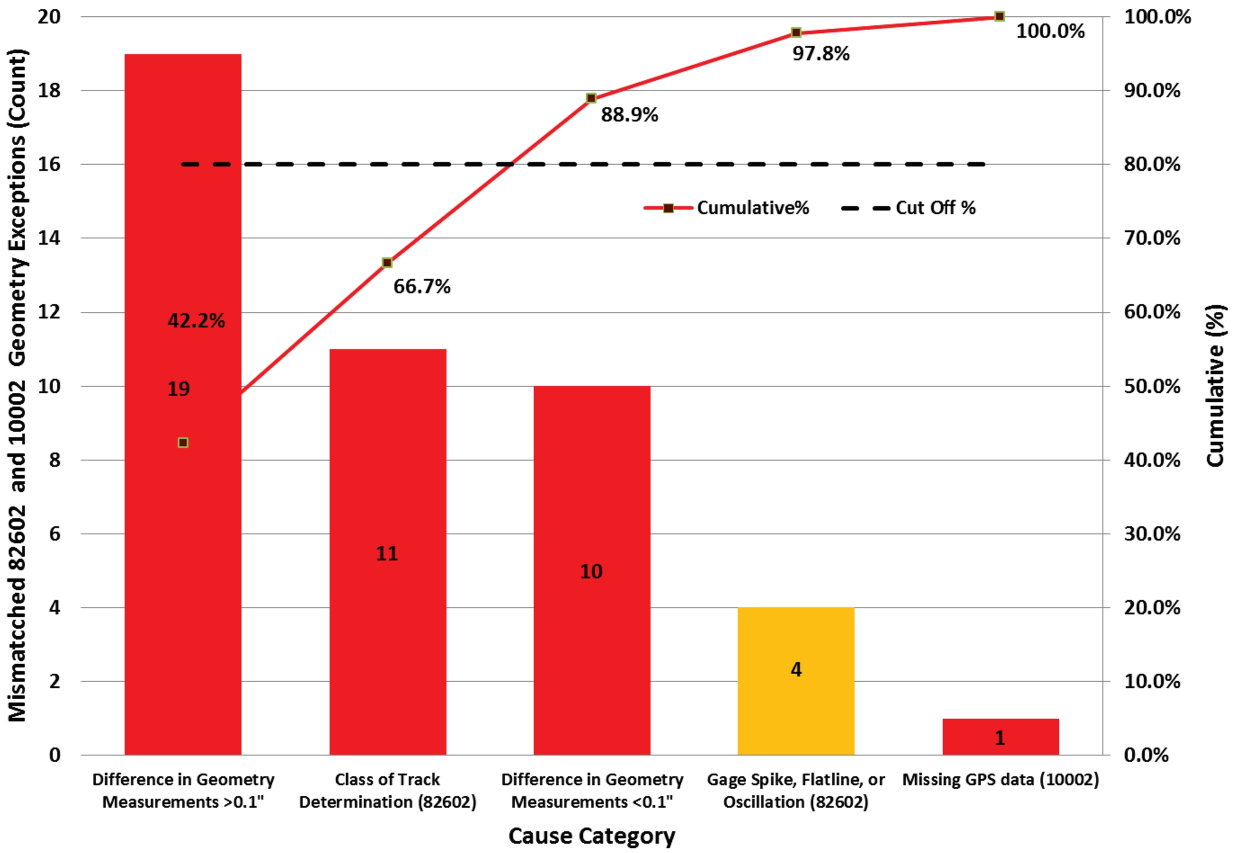

Figure C59: Distribution of Mismatched Geometry Exceptions into Categories of Causes

19.1 Exceptions not Detected by ATGMS

The Pareto chart in Figure C59 illustrates the distribution of 41 10002-reported geometry exceptions not reported by ATGMS by different cause categories. Consideration of Figure C59 shows the following:

- Eleven of the 41 10002-reported geometry exceptions not detected by ATGMS were caused by ATGMS' erroneous class of track determination, which is based solely on the vehicle's speed. Determination of track class is a functionality that can be improved through a number of different measures including manual review and correction or detailed, up-to-date geo-referenced track class designations that could be provided by individual railroads.
- Twenty-nine out of the 41 10002-reported geometry exceptions not detected by ATGMS were caused by differences in geometry measurements between the 10002 manned system and ATGMS attributed to differences in system installations (truck-mounted versus carbody-mounted) and minor system differences such as offsets.
- One out of 63 10002-reported geometry exceptions not detected by ATGMS was due to missing 10002 GPS data, therefore it was not possible to align associated foot-by-foot geometries for analysis.

Once causes for mismatched geometry exceptions are identified, their effect on different types of reported geometry exceptions can be identified. Listed in Table C25 are 41 10002-reported geometry exceptions not detected by ATGMS distributed into 11 geometry exception types and 4 cause categories in Figure C59. As indicated by the numbers in Table C25, differences in geometry measurements being more than 0.1 inches was the leading cause for geometry exceptions that were not detected by ATGMS.

Table C25: Distribution of 10002-Reported Geometry Exceptions Not Detected by ATGMS by Exception Type

		Cause Category				
		Not Detected	**Difference in Geometry Measurement > 0.1 inches**	**Difference in Geometry Measurement < 0.1 inches**	**Class of Track Determination**	**Missing GPS Data (10002)**
Geometry Exception Type	**Gage Change**	2	2	0	0	0
	L Prof 31’	5	2	1	2	0
	R Prof 31’	8	5	2	1	0
	L Prof 62’	3	1	2	0	0
	R Prof 62’	6	2	2	1	1
	L Prof 124’	1	0	0	1	0
	R Prof 124’	5	1	1	3	0
	L Align 62’	4	3	1	0	0
	R Align 62’	4	2	1	1	0
	L Align 124’	2	0	0	2	0
	R Align 124’	1	1	0	0	0
	TOTAL	**41**	**19**	**10**	**11**	**1**

19.2 Exceptions Not Reported by ATGMS

The Pareto chart in Figure C59 indicates that 4 out of 45 10002-reported geometry exceptions were detected by ATGMS but deleted by ATGMS automated exception filters. The automated filters detected spikes and flat lines in the foot-by-foot gage measurement associated with these exceptions. Spikes and flat lines could be caused by factors such as direct sun glare or reflections from the ballast.

Table C26 lists the four 10002-reported geometry exceptions detected but deleted by ATGMS automated exception editor distributed into two geometry exception types and two cause categories previously identified in Figure C59. Spikes and flat lines in gage measurement affected 31-foot cord profile measurements and oscillations in foot-by-foot geometry measurements affected 62-foot cord profile measurements, respectively.

Table C26: Distribution of 10002-Reported Geometry Exceptions Detected but Deleted by ATGMS by Exception Type

		Cause Category		
		Detected but Deleted	**Gage Spike and Flat Line (ATGMS)**	**Gage High Frequency Oscillations (ATGMS)**
Exception Type	**R Prof 31’**	**3**	3	0
	R Prof 62’	**1**	0	1
	TOTAL	**4**	**3**	**1**

Analysis presented in this report shows that one factor affecting ATGMS performance is track class determination. However, due to fairly consistent operating speeds on the NEC including Amtrak’s practice of quickly achieving posted speeds, track class determined by ATGMS in Amtrak’s NEC operations was generally more accurate than track classes determined by ATGMS in other operations involving freight corridors[1]. Following multiple evaluations similar to the one documented here, FRA sponsored the development of a web application for remote editing of ATGMS exceptions. With the use of this application, ATGMS generated exceptions are presented to an experienced operator located at a remote site for review and editing. Based on available information such as track charts, timetables and aerial images, the user of the application will be able to provide critical inputs into the proper identification of tracks over which the system is traversing and the establishment of track class. It is conservatively anticipated that operation of this web application will improve ATGMS track class determination by close to 90 percent, reducing the number of exceptions in this category from 11 exceptions to 1.

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[1] ENSCO Document SERV-REPT-0000507 “Comparison of DOTX221 ATGMS and DOTX220 TGMS Geometry Exceptions and Foot-by-Foot Geometry – Summary Report.”

20. ATGMS and 10002 Foot-by-Foot Geometry Data Comparison

Geometry exceptions were used as markers for retrieving corresponding ATGMS and 10002 foot-by-foot geometry data for comparison. Out of 63 10002-reported geometry exceptions, only 35 were used for identifying foot-by-foot geometry measurements for detailed comparison. Twenty-eight of the 10002-reported geometry exceptions were excluded because:

- Twenty-seven represented multiple exceptions types, meaning that at the same location or within a range of several feet, various geometry exceptions existed
- One had incomplete or missing foot-by-foot geometry measurements

The foot-by-foot geometry measurements identified by the above mentioned 35 geometry exceptions were reviewed to remove measurement outliers and measurements made below cut off speed of 28 miles per hour (mph) for track geometry calculations. Adjustments were made by removing a small segment of affected measurements from all geometry channels.

This process resulted in more than 17,500 feet of corresponding ATGMS and 10002 foot-by-foot geometry measurements for which resulting statistics were compared against accepted ATIP repeatability thresholds for track geometry data collected from multiple vehicles. These thresholds are presented in Table C27 and statistics of analyzed data set is presented in Table C28.

Table C27: Repeatability Thresholds for Foot by Foot Track Geometry Data Multiple Vehicles

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
Profile (Inches)	0.04419	0.08838
Alignment (Inches)	0.04419	0.17675
Crosslevel (Inches)	0.04419	0.08838
Curvature (Deg/100’)	0.01414	0.21210
Gage (Inches)	0.04419	0.08838

Table C28. Statistics of Difference Between ATGMS and 10002 Foot-by-Foot Track Geometry Data April 2013

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
L Profile 31’	0.00000	0.0439
L Profile 62’	-0.00000	0.0455
L Profile 124’	0.00032	0.0523
L Alignment 31’	0.00017	0.0394
L Alignment 62’	0.00018	0.0614
L Alignment 124’	-0.00000	0.1195
R Profile 31’	0.00015	0.0559
R Profile 62’	0.00000	0.0579
R Profile 124’	0.00044	0.0689
R Alignment 31’	0.00000	0.0649
R Alignment 62’	0.00000	0.0786
R Alignment 124’	-0.00030	0.1293
Crosslevel	-0.02105	*0.0975*
Curvature (Deg/100’)	0.00962	0.0528
Gage	*0.05663*	0.0554

Results indicate that mean difference of gage and standard deviations of crosslevel measurements exceed the multiple vehicle repeatability thresholds. Mean differences and standard deviations for all other measurement parameters meet multiple vehicle repeatability thresholds.

21. Conclusions and Recommendations

Over 914 miles of track geometry measurements collected on April 2 and 3, 2013, by the ATGMS on Amtrak's 82602 while operated in consist with Amtrak's 10002 manned inspection vehicle over Amtrak's NEC between Washington, DC, and Boston, MA. Exceptions to the track geometry limits specified in the FRA Track Safety Standards reported by Amtrak's manned system were considered as "ground truth" and used to assess performance of the ATGMS through comparison of the reported exceptions. A subset of the exceptions reported by the Amtrak system were used to identify areas for comparison of foot-by-foot track geometry data collected by the unmanned and manned systems.

Comparison of foot-by-foot data collected by both systems shows that track geometry measured by ATGMS compared well with that collected by Amtrak's manned inspection vehicle.

Over the survey considered, Amtrak's 10002 reported 63 exceptions. Not all ATGMS-generated exceptions matched the 63 exceptions reported by the Amtrak manned system. Mismatched exceptions were reviewed and the following five categories of causes were identified:

- Difference in Geometry Measurements >0.1 inches
- Class of Track Determination
- Difference in Geometry Measurements <0.1 inches
- Gage Spike and Flat Line in ATGMS
- Missing GPS Data in 10002

Review of mismatched exceptions identified ATGMS automated, speed-based logic for class of track determination as one factor affecting ATGMS performance. Following assessment of the performance of the ATGMS compared to that of a manned system, a web application for remote editing of ATGMS detected exceptions by an operator was developed to augment ATGMS track class determination logic and automated exception editing until ATGMS technology matures to the point that it can reliably produce results comparable to manned operations.

Based on observations during operations and the results of analysis presented in this report, ENSCO has identified the following areas of ATGMS technology for further improvement:

1. **Track Class Determination** - Exceptions to track geometry limits defined in FRA's Track Safety Standards are different for each track class. Track class and associated posted speed are used to apply the proper track geometry limits. Therefore, accurate determination of track class will improve ATGMS performance in reporting valid exceptions. In 2012, as part of ENSCO's internal research and development efforts, an approach for accurate determination of track number, and by extension track class and posted speed, based on railroad-provided information was developed and tested using limited information provided by a Class I railroad. This approach can be further improved and used to increase ATGMS performance in reporting valid exceptions where railroad-provided information
2. **Automated Geometry Exception Filters** – Automated geometry exception filters inspect validity of an exception by analyzing associated foot-by-foot geometry measurements according to a set of empirically derived limits and signal processing

algorithms. Empirically derived limits are based on review of many reported exceptions of the same type by FRA ATIP's manned track geometry inspection vehicles. Signal processing algorithms are designed to detect outliers and anomalies caused by system malfunctions and/or environmental factors such as spikes, flat lines, and high frequency oscillations in geometry measurements. Both empirically derived limits and signal processing algorithms can be further tuned to improve ATGMS performance in reporting valid exceptions. In addition, automated geometry exception filters "exception list" can be expanded to include more exception types to reduce the number of exceptions that could not be classified by the filters, therefore, marked as "not reviewed".

3. **Lens Protection System** – Through ENSCO internal efforts, a passive protective cover for carbody-mounted ATGMS' optics have been developed and evaluated. Use of this protective cover on another carbody-mounted ATGMS installation has shown that it improves quality of collected data by reducing accumulation of dirt on the optics and protects them from hits by flying debris.

Abbreviations and Acronyms

AER	Advisory Exception Report
ALD	Automatic Location Detector
ARMS	Autonomous Ride Monitoring System
ATGMS	Autonomous Track Geometry Measurement System
ATIP	Automated Track Inspection Program
CAN	Controller Area Network
CSX	CSX Transportation
CTS	Curve, Tangent, and Spiral
DGPS	Differential Global Positioning System
DOD	Depth of Discharge
EPS	Electrical Power System
ELS	Escanaba and Lake Superior Railroad
FRA	Federal Railroad Administration
GPS	Global Positioning Satellite
GUI	Graphical User Interface
HEP	Head End Power
ISO	International Standards Organization
LPS	Laser Protection System
MARC	Maryland Area Regional Commuter
MCO	Mid-chord Offset
MPH	Miles Per Hour
MTA	Maryland Transit Administration
Amtrak	National Railroad Passenger Corporation
NCER	Non-Compliant Exception Report
NEC	Northeast Corridor
NIST	National Institute of Standards and Technology
PMA	Permanent Magnet Alternators
PTC	Positive Train Control
RD&T	Office of Research, Development and Technology
RPM	Revolutions Per Minute
RRS	Office of Railroad Safety

RTGMS	Remote Track Geometry Measurement System
SCU	Signal Conditioning Unit
TAR	Track Assessment Report
TCR	Track Condition Report
TGMS	Track Geometry Measurement System
UP	Union Pacific Railroad
UPS	Uninterruptable Power Supply
V/TI	Vehicle/Track Interaction

Exhibit 2

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FRA AUTONOMOUS TRACK GEOMETRY MEASUREMENT SYSTEM TECHNOLOGY DEVELOPMENT - PAST, PRESENT, AND FUTURE

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ABSTRACT

The Federal Railroad Administration's (FRA's) Office of Research and Development has undertaken a multi-phase research program focused on the development and advancement of Autonomous Track Geometry Measurement Systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. Benefits of widespread use of ATGMS technology include reduced life-cycle cost of inspection operations, minimized interference with revenue operations, and increased inspection frequencies.

FRA's Office of Research and Development ATGMS research program results have demonstrated that the paradigm of track inspection and maintenance practices, information management and, eventually, government regulations will change as a result of widespread use of ATGMS technology by the industry. A natural consequence of increased inspection frequencies associated with ATGMS is the large amount of actionable information produced. Therefore, changing existing maintenance practices to address a larger number of identified track issues across large geographic areas will be a challenge for the industry. In addition, managing ATGMS data and assessing the quality of this information in a timely manner will be challenging.

This paper presents an overview of the FRA's ATGMS research program with emphasis on its evolution from a proof-of-concept prototype to a fully operational measurement system. It presents the evolution of ATGMS technology over time including the development of a web-based application for data editing, management and quality assurance. Finally, it presents FRA's vision for the future of the ATGMS technology.

INTRODUCTION

Autonomous track inspection is a process in which the track is inspected using unattended instrumentation with minimal direct involvement from human operators. The technology has been developed utilizing revenue service trains equipped with data collection equipment employing wireless communications to provide inspection data with dramatically increased frequency and reduced cost.

Since 2000, Autonomous Ride Quality and Vehicle/Track Interaction Monitoring systems have been used by National Railroad Passenger Railroad Corporation (Amtrak®), Maryland Transit Administration's (MTA) MARC commuter service, and Union Pacific Railroad [1]. Building on the experience of implementation and application of these systems, FRA took steps to develop and evaluate an autonomous track geometry measurement system to report track issues in near real-time to remote stakeholders.

The objectives of the FRA's ATGMS research program were to create a relatively low-cost, modular, unattended, self-powering geometry measurement system that can be deployed on standard rail equipment to collect and distribute accurate track geometry data. During development, the FRA's Office of Research and Development has collaborated with FRA's Office of Safety to demonstrate the use of ATGMS technology for track safety assessment throughout the United States.

ATGMS TECHNOLOGY ARCITECHURE

A modular architecture was employed in the FRA's ATGMS to allow for maximum flexibility in incremental development, evaluation, and implementation of system capabilities. The architecture consists of three main modules: onboard Data Collection Unit, remote Data Processing Servers, and a Cellular Communication Link to allow for the exchange of information between the Data Collection and Data Processing modules. The Data Collection Unit includes ATGMS sensors, electronics, communication devices, and associated mechanical assemblies that constitute the measurement system on the track-bound vehicle. Mounted on a rugged mechanical platform, optical sensors capture the contour of the rails as well as their location with respect to the platform; inertial sensors capture the platform's position in space as the vehicle travels on track. An axle-mount rotary encoder measures distance travelled and a Differential Global Positioning System captures highly accurate location information. The Data Collection module collects, synchronizes, and packages foot-by-foot raw sensor data and system diagnostic information for transmission from the measurement system to Data Processing Servers via a commercial Cellular Communication Link.

The manner in which power is provided to the Data Collection module depends on the type of vehicle. On rail cars with available head-end power (HEP), such as passenger coaches and locomotives, a rugged Uninterruptable Power Supply (UPS) is used to minimize power disruptions to allow for operations, at the end of survey to complete transfer of queued data from the onboard Data Collection module to the remote Data Processing Servers, and orderly shutdown of ATGMS when the railcar loses power for an extended period of time. On freight railcars without HEP, the power module consists of a battery bank that is charged by a solar power system. Supplemental charging power can be provided by a variety of other sources including specially designed diesel generators or fuel cells.

The Data Processing Server module includes features for communication with the onboard Data Collection module, processing of incoming data, transmission of reports and other important messages, as well as data archiving. Following receipt of data from the onboard module, server-based software performs a series of quality checks to ensure continuity of data and subsequently converts sensor data into foot-by-foot geometry measurements while diagnostic information transferred to the servers is electronically sent to the technical support team as Status and Alert Messages. Processed foot-by-foot geometry measurements are further analyzed to detect geometry measurements outside established thresholds. The validity of the detected exception is checked to remove false positives. Information regarding confirmed exceptions is sent out to survey participants in a variety of formats.

Recent efforts have focused on the development of a secure web-based application to the Data Processing Server that provides authorized reviewers access to ATGMS database for near real-time analysis of exception data. A reviewer can select a specific or range of surveys and perform all aspects of quality assurance. The reviewer can make necessary adjustments to control parameters, and review or update the status of geometry exceptions using electronic timetables, track charts and maps. Geometry exceptions can then be sent to a list of authorized recipients. Reviewers can also remotely identify and address data quality issues caused by specific data collection module malfunctions.

ATGMS TECHNOLOGY DEVELOPMENT PLAN

To achieve its vision of autonomous geometry measurement systems, FRA created a multi-phase development plan to guide the research and evaluation efforts as well as the transition of ATGMS technology to the railroad industry:

Stage 1: Long Term Pilot with Standard Inspection Technology

The first stage centered on the creation of the basic elements of a ruggedized pilot ATGMS. Research focused on using commercial, off-the-shelf equipment to facilitate early development and evaluation, with emphasis on cellular communication and data transmission, location information tagging, and geometry data and exception processing. The Data Collection module was configured to measure track geometry, analyze the measurements for any locations exceeding established limits, and transmit "exception reports" to the server for storage and transmission to survey stakeholders. Automated filters employing a variety of statistics-based algorithms and logic rules were used to identify and eliminate "false" exceptions. Between January 2008 and March 2011 the pilot ATGMS was operated on Amtrak 39000, a Superliner II railcar, during revenue service operations within Amtrak's Auto Train service that runs between Lorton, VA, and Sanford, FL, over CSX Transportation track. During that time ATGMS surveyed almost 460,000 miles of track, an average of approximately 153,000 miles per year. This extensive testing allowed identification of system problems and limitations, facilitating design modifications that moved ATGMS technology towards increased robustness and reliability.

Stage 2: Simulation of Standard Revenue Operations

The major accomplishments for this stage of development included transmission of all raw sensor data collected by the

Data Collection module to the Data Processing Servers, and to test the ATGMS over a variety of track conditions in consist with a manned geometry car. The objectives of this development stage were to demonstrate ATGMS accuracy and increase the autonomy of operation through automatic data transfer. The ATGMS was transferred to FRA's DOTX221, a sleeper-lounge car, and operated in consist with FRA's DOTX220 manned inspection vehicle

Several aspects of the ATGMS technology were either developed and/or perfected during this stage including automated health and status reporting, and self-diagnostics and auto-recovery features. All components of the Data Collection module were mounted outside, under or on the roof, of the vehicle. A weather sealed enclosure was used to house sensitive electronics. An hourly "Status" email message providing information on UPS battery voltage, hard drive and processing unit usage, temperature inside the weather sealed enclosure housing electronics, railroad being surveyed, miles surveyed since last Status message, total number of exceptions reported during the current survey, etc. is sent out automatically by the Data Collection module. Sensor malfunctions were reported automatically via an on-demand "Alert" email message identifying the sensor and type of malfunction such as sensor saturation.

Self-diagnostic and auto-recovery features on the Data Collection module detect system soft-failures such as blockage in data transfer to the Processing Servers due to prolonged loss of Cellular Communication Link and/or interruptions in communication among onboard subsystems, corruption of data or configuration files, etc. and initiate a pre-defined sequence of actions to orderly shutdown and restart the system.

A major aspect of this phase of development was the comparison of geometry data collected with the autonomous system and the manned geometry system to identify and address any differences. The combined systems were tested as part of FRA's Automated Track Inspection Program (ATIP) surveys conducted over Amtrak passenger routes between September 2011 and June 2013. This testing demonstrated that the two systems produced data of equal quality. Differences between measured geometry data were within acceptable limits established for geometry measurements from multiple vehicles for this effort. These limits are characterized by standard deviations of 0.088 inch (2.24 mm) for gage, crosslevel and profile/surface mid-chord offsets using a 62-foot chord, 0.177 inch (4.49 mm) for alignment mid-chord offsets using a 62-foot chord and 0.2 degrees for curvature. Data variability was comparable to differences seen between manned systems on different vehicles.

Exceptions generated by the ATGMS and the manned system were compared and differences in reporting were attributed to (a) ATGMS speed-based class of track determination logic, (b) difference in geometry measurements from the two systems, (c) ATGMS automated exception validation logic versus crew observation of track features such as switches, and (d) erroneous deletion and/or validation of exceptions on both systems.

Subsequent research efforts focused on developing and implementing a secure web-based application for near real-time review and validation of geometry exceptions as part of FRA's data management and quality assurance processes. Using this application, a reviewer makes necessary adjustments to the control parameters such as track number and track class based on the latest information provided by railroads to validate geometry exceptions. The confirmed exceptions can then be sent to a list of designated recipients. Information available to reviewers to facilitate their decision process include detailed maps using a Google^{TM} Map display of geographical location of the selected data, displays of foot-by-foot track geometry measured in areas of interest and railroad-provided timetables and track charts.

Stage 3: Advancing Measurement Technology

During this stage a carbody-mounted ATGMS was developed and evaluated. The objective was to minimize interference with truck and wheel set maintenance activities, better protect the measurement platform from flying debris and mud, and allow for installation of ATGMS on a wide range of vehicle designs with a lower installation and maintenance cost.

The major accomplishments for this stage of development included demonstration of the new sensor and processing algorithms to account for new measurement techniques that measured track from a location further away from the track. For demonstration and evaluation purposes, a carbody-mounted ATGMS was installed and operated on Amtrak 82602, an Amlfeet I passenger car, in Amtrak revenue service on the Northeast Corridor between September 2012 and August 2013. Its performance was evaluated and compared to Amtrak's 10002 manned geometry inspection vehicle equipped with a truck-mounted geometry measurement system.

This testing demonstrated that the carbody-mounted ATGMS produced data of equal quality when compared with a truck-mounted track geometry measurement system. Differences between measured geometry data were within acceptable tolerances established for geometry measurements from multiple vehicles for this effort. Exceptions generated by the carboy-mounted ATGMS and the manned system were compared and differences in reporting were attributed to the same factors identified during Stage 2 demonstration with ATGMS speed-based class of track determination having less effect due to rapid acceleration and deceleration of the vehicle in Amtrak revenue service on the Northeast Corridor.

Stage 4: Development of Energy Harvesting Technology

The fourth stage targeted development and evaluation of the technologies that allow for ATGMS to be deployed on freight vehicles and other rail cars without electrical power. Solar, wind, fuel cell, and fossil fuel power sources under different operational and environmental conditions such as vehicle speed and solar radiation values were analyzed using a computer model to simulate power system's input and output electrical loads and to identify an optimum configuration.

This analysis identified the appropriate operating temperature range, mechanical, electrical, and safety requirements for the equipment, battery size and charge cycle, solar panel capacities, desired charge controller features, and technical and operational specifications for a candidate diesel generator.

It identified operating voltages of 24 Volts and 48 Volts for the ATGMS electrical power supply to maximize use of the off-the-shelf components and facilitate future use of other secondary power sources such as fuel cells.

Results of this analysis and historical data from solar power systems operated on railcars indicated that solar power can be effectively used as the primary source of power. Prototype devices for wind power generation were fabricated and field tested with mixed results.

Finally, it was shown that converting the ATGMS to operate on DC power instead of AC power offers significant performance improvements.

Stage 5: Future Demonstration of System in Freight Service

In the fifth, and current development stage, ATGMS technology will be demonstrated in freight service. Plans are underway to deploy the FRA carbody-mounted ATGMS on a typical box car for demonstration on railroads throughout the country in late 2014. Results of Stage 5 activities are anticipated to be available shortly after completion of the freight operation demonstration in early 2015. Technology and procedures developed by FRA throughout the first four stages of this program will be relied upon for demonstration testing done throughout Stage 5.

FRA OFFICE OF SAFETY OPERATION OF ATGMS TECHNOLOGY

The focus of FRA's Office of Research and Development during during 2013 ATIP operations conducted under Stage 2 was the evaluation of ATGMS technology and procedures with the goal of providing a sustainable track inspection system for FRA's Office of Safety ATIP operations.

FRA Office of Safety's use of ATGMS without an accompanying manned survey car started in Washington, D.C., on July 29, 2013, and ended in Washington, D.C., on September 29, 2013, covering more than 19,000 miles of track. In near real-time, as exception data become available in the database, a reviewer used the web-based application to correct for actual track class as well as individual track number and to validate individual exceptions and overall track measurement quality by considering foot-by-foot geometry data, system health information and other system data.

Confirmed exceptions were sent as Non-Compliance Exception Reports (NCERs). Track Assessment Reports (TARs) covering surveyed track within territory of individual railroads were sent out at the end of each survey, when all track exceptions were confirmed by operators. The TARs include a tabular exception list as well as a summary list of all confirmed track geometry exceptions for the reported geographical limits. NCERs and TARs were sent to railroad representatives and FRA personnel at the same time.

As part of the data quality assurance process, foot-by-foot geometry data collected on three selected track segments at different times during the 2013 ATIP assessment were compared to evaluate the overall consistency of geometry conditions. This evaluation data included two sets of geometry data collected on the same track between Los Angeles, CA, and Oakland, CA, on consecutive days; two sets of geometry data collected forty days apart on the same track between Memphis, TN, and New Orleans, LA; and two sets of geometry data collected nineteen days apart on the same track between Tempe, TX, and San Antonio, TX. Statistics of differences between the respective sets of collected geometry data on these track segments confirmed ATGMS' repeatability throughout the assignment.

Aside from minor and expected hardware and software issues that were addressed during scheduled maintenance stops, performance of the web-based application for information management and quality assurance met expectations; ATGMS geometry exceptions reported via the web-based application were routinely field verified by railroad maintenance personnel.

CONCLUSIONS

FRA's vision is to improve track safety and maintenance practices by enhancing conditional awareness through the use of autonomous inspection systems. In order to fulfill this vision, FRA's Office of Research and Development planned and conducted a five-stage ATGMS research program with the objectives of creating a relatively low-cost, modular, unattended, self-powering geometry measurement system that can be deployed on standard rail equipment, including freight cars, to collect and distribute accurate track geometry data while running in a standard revenue train.

FRA's ATGMS research program has demonstrated ATGMS technology in standard revenue train for routine track inspection. It also demonstrated successful implementation of advanced sensing technologies and power systems that facilitate deployment of ATGMS on standard rail equipment, with efforts underway to demonstrate its operation in freight service. It has also identified several technology areas for further improvement including the ability to identify and resolve ATGMS maintenance issues in a manner that minimizes disruption to geometry inspection operations, means and methods for autonomous system calibration and field verification, redundancy of electronics critical to autonomous operation, and automated class of track determination for geometry exception editing.

ACKNOWLEDGMENTS

This paper presents the efforts of many people and organizations serving a progressive, ongoing effort to develop and promote autonomous track geometry measurement for widespread use in the railroad industry. The FRA's Office of Research and Development as well as its Office of Safety, particularly FRA's ATIP staff, spearheaded this effort in concert with ENSCO, Inc. of Springfield, Virginia. The authors would like to express their gratitude to Dr. Magdy El-Sibaie and Mr. Ali Tajaddini for their leadership and guidance during the early days of development.

The implementation of this technology could not have taken place in the manner in which it did without the essential logistical and in-kind support of both CSX Transportation and Amtrak who facilitated both short-term and long-term pilot studies at critical times within the research program. The authors would like to thank Ron Bright and Larry Biess of CSX as well as Paul Steets and Mike Trosino of Amtrak for their efforts to facilitate this important research.

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1. Carr, G., Tajaddini, A., Nejikovsky, B. “Autonomous Track Inspection Systems – Today and Tomorrow,” AREMA 2009 Annual Conference and Exposition, September 20-23, 2009, Chicago, IL.

Exhibit 3

Development and Use of FRA Autonomous Track Geometry Measurement System Technology

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Number of Words (including Figures) are 4204

ABSTRACT

The Federal Railroad Administration's (FRA's) Office of Research, Development and Technology has long advocated for the development and advancement of Autonomous Track Geometry Measurement Systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data. Routine use of ATGMS technology by the rail industry will eventually lead to minimized interference of inspections to revenue operations, increased inspection frequencies and reduced life-cycle cost of inspection operations, all of which will lead to improved safety and maintenance planning.

FRA's ATGMS research program has demonstrated the potential benefits and uses of the unmanned inspection approach as well as its impact on information management. A natural consequence of increased inspection frequencies associated with ATGMS is the large amount of actionable information produced. Therefore, managing ATGMS data and assessing the quality of this information in a timely manner will be challenging as will be the changes to current maintenance practices to address a greater number of identified track issues across large geographic areas in an efficient and practical manner.

This paper presents an update on the accomplishments of the FRA's ATGMS research and development program with emphasis on its evolution from a proof-of-concept prototype to a fully operational measurement system. The paper also provides a summary of how the FRA Office of Safety is employing unmanned inspection in track assessments, lessons learned from the implementation of this approach and FRA's vision for the role of this technology in track inspection and safety assurance.

INTRODUCTION

Autonomous track inspection is a process in which the track is inspected using unattended instrumentation with minimal direct involvement from human operators. Building on the experience of implementation and application of autonomous ride quality and vehicle/track interaction monitoring systems by Amtrak, Maryland Transit Administration's (MTA) and Union Pacific Railroad, FRA took steps to develop and evaluate an autonomous track geometry measurement system to report track issues in near real-time to remote stakeholders (*1*).

To that end, the FRA Office of Research, Development and Technology undertook a research program focused on the advancement of autonomous track geometry measurement systems (ATGMS) that improves rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. FRA's vision is the development and use of relatively low cost, self-powering geometry measurement systems on a wide range of rail vehicles, including freight cars, that:

- Reduce the life-cycle costs of geometry measurement operations;
- Eliminate interference with revenue operations;
- Increase inspection frequencies and productivity;
- Provide data of the highest quality possible.

The FRA's goal is not necessarily to replace manned automated inspection systems as a quality assurance tool, but to create and facilitate the use of more flexible, efficient tools for use in quality control and maintenance planning activities.

ATGMS TECHNOLOGY ARCHITECTURE

A modular architecture was employed in the FRA's ATGMS to allow for maximum flexibility in incremental development, evaluation, and implementation of system capabilities. The architecture consists of four main modules: onboard Data Collection Module, remote Data Processing Servers, a Cellular Communication Link to allow for the exchange of information between the Data Collection Module and Data Processing Servers, and web-based applications that provide authorized users access to the ATGMS database for near real-time analysis of track data.

As shown in Figure 1 the Data Collection Module includes sensors, electronics, communication devices, and associated mechanical assemblies that constitute the measurement system on the track-bound vehicle. Mounted on a rugged mechanical platform, inertial sensors capture the platform's position in space as the vehicle travels on track while the optical sensors capture the contour of the rails as well as their location with respect to the platform. An encoder measures distance travelled and a Differential Global Positioning System captures highly accurate location information. The Data Collection Module collects, synchronizes, and packages foot-by-foot raw sensor data and system diagnostic information for transmission from the measurement system to the Data Processing Server via a commercial Cellular Communication Link.

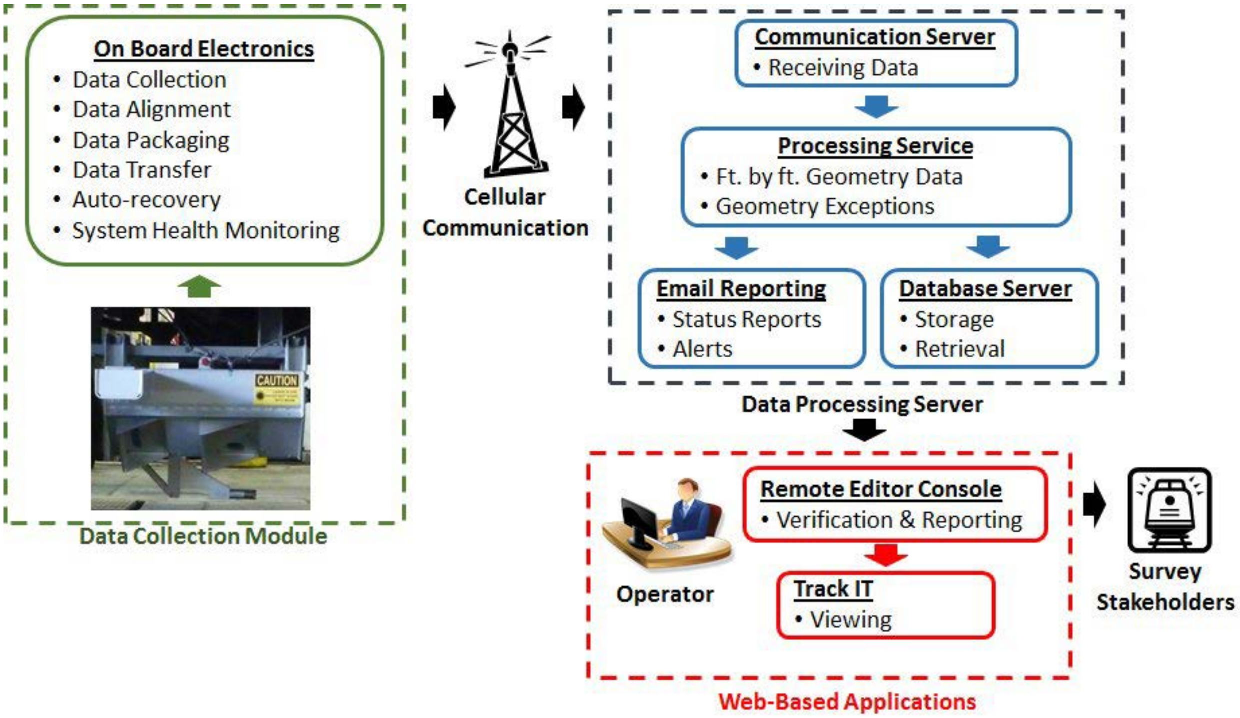


Figure 1. FRA's ATGMS Technology Architecture

The manner in which power is provided to the Data Collection Module depends on the type of vehicle. On rail cars with available head-end power (HEP), such as passenger coaches and locomotives, a rugged Uninterruptable Power Supply (UPS) is used to minimize power disruptions to allow for operations at the end of survey to complete transfer of queued data and orderly shutdown of ATGMS when the railcar loses power for an extended period of time. On freight railcars without HEP, the power module consists of a battery bank that is charged by a solar power system. Supplemental charging power can be provided by a variety of other sources including specially designed diesel generators or fuel cells.

The Data Processing Server module includes features for communication with the onboard Data Collection Module, processing of incoming data, transmission of important status messages, as well as data archiving. Following receipt of data from the onboard module, the server-based software performs a series of quality checks to ensure continuity of data and subsequently converts sensor data into foot-by-foot geometry measurements while diagnostic information transferred to the servers is electronically sent to the technical support team as Status and Alert Messages. Processed foot-by-foot geometry measurements are further analyzed to detect geometry measurements outside established thresholds. The validity of the detected exception is checked to remove false positives and a record of all exceptions is sent out to survey reviewers.

The web-based Remote Editor Desk application provides authorized reviewers access to ATGMS database for near real-time analysis of geometry data. An operator can select one or more surveys and perform all aspects of quality assurance on the data. The user is provided the ability to make necessary adjustments to survey parameters such as track class and track number or update the status of geometry exceptions. Inputs to these decisions are facilitated by use of electronic timetables, track charts, detailed maps using a Google^{TM} Map display of geographical location of selected data, displays of foot-by-foot track geometry measured in areas of interest and railroad-provided timetables. The results of the exception review process can then be sent to a list of authorized recipients including railroad personnel. Reviewers can also remotely identify and address data quality issues caused by specific Data Collection Module malfunctions and develop recommended actions to be performed during scheduled maintenance stops.

ATGMS TECHNOLOGY DEVELOPMENT PLAN

To achieve its vision of autonomous geometry measurement systems, FRA created a multi-phase development plan to guide the research and evaluation efforts as well as the transition of ATGMS technology to the railroad industry. Highlights of this development, which has been previously detailed (*2*), include the following:

Stage 1: Long Term Pilot with Standard Inspection Technology

The first stage centered on the creation of the basic elements of a ruggedized pilot ATGMS. Commercial, off-the-shelf equipment was employed to facilitate early development and evaluation. The original Data Collection Module was designed to alert stakeholders to areas of concern. The system was configured to measure track geometry, analyze the measurements for any locations exceeding established limits, and transmit “exception reports” to the server for storage and transmission to survey stakeholders. Early efforts focused on the creation of automated filters employing a variety of statistics-based algorithms and logic rules to identify and eliminate “false” exceptions. The pilot ATGMS was operated over CSX track between Lorton, VA, and Sanford, FL, on Amtrak 39000, a Superliner II railcar, in revenue service operations within Amtrak’s Auto Train service; an illustration of the measurement equipment located under the vehicle is included as Figure 2. Between January 2008 and March 2011, ATGMS surveyed almost 460,000 miles of track, an average of approximately 153,000 miles per year. This extensive testing allowed identification of system problems and limitations, facilitating design modifications that moved the technology towards increased robustness and reliability.

Figure 2. FRA’s Truck-Mounted Pilot ATGMS on Amtrak Superliner 39000

Stage 2: Simulation of Standard Revenue Operations

This stage centered on the demonstration of ATGMS accuracy in wider scale revenue operations and increased functionality. During this stage, the system was re-engineered to transmit all raw sensor data collected by the Data Collection Module to the Data Processing Servers in order to allow for automatic transfer of all track geometry measurements. Other key features of the technology that were either developed or refined during this stage included:

- Automated health and status reporting;
- Self-diagnostics and auto-recovery features;
- Improved hourly “status” email messages that provided detailed system and survey information;
- On-demand “Alert” messages that automatically report sensor malfunction;
- Self-diagnostic and auto-recovery features on the Data Collection Module to detect communication issues, corruption of data or configuration files, etc. and initiate a pre-defined sequence of actions to orderly shutdown and restart the system.

These features were successfully demonstrated during operation of the unmanned system on FRA’s DOTX221, a sleeper-lounge car operated in consist with FRA’s DOTX220 manned inspection vehicle. DOTX221 and the installation of the autonomous system are shown in Figure 3. The performance of the unmanned system was compared to that of a traditional geometry inspection vehicle as part of FRA’s Automated Track Inspection Program (ATIP) surveys conducted over Amtrak passenger routes between September 2011 and June 2013. This testing demonstrated that the two systems produced geometry data of equal quality with differences between measured geometry data within acceptable limits established for geometry measurements from multiple vehicles for this effort. Exceptions generated by the ATGMS and the manned system were compared and differences in reporting were attributed to:

- ATGMS speed-based class of track determination logic;
- Difference in geometry measurements from the two systems;
- Automated exception validation logic used with ATGMS as compared to crew observation of track features such as switches;
- Erroneous deletion and/or validation of exceptions.

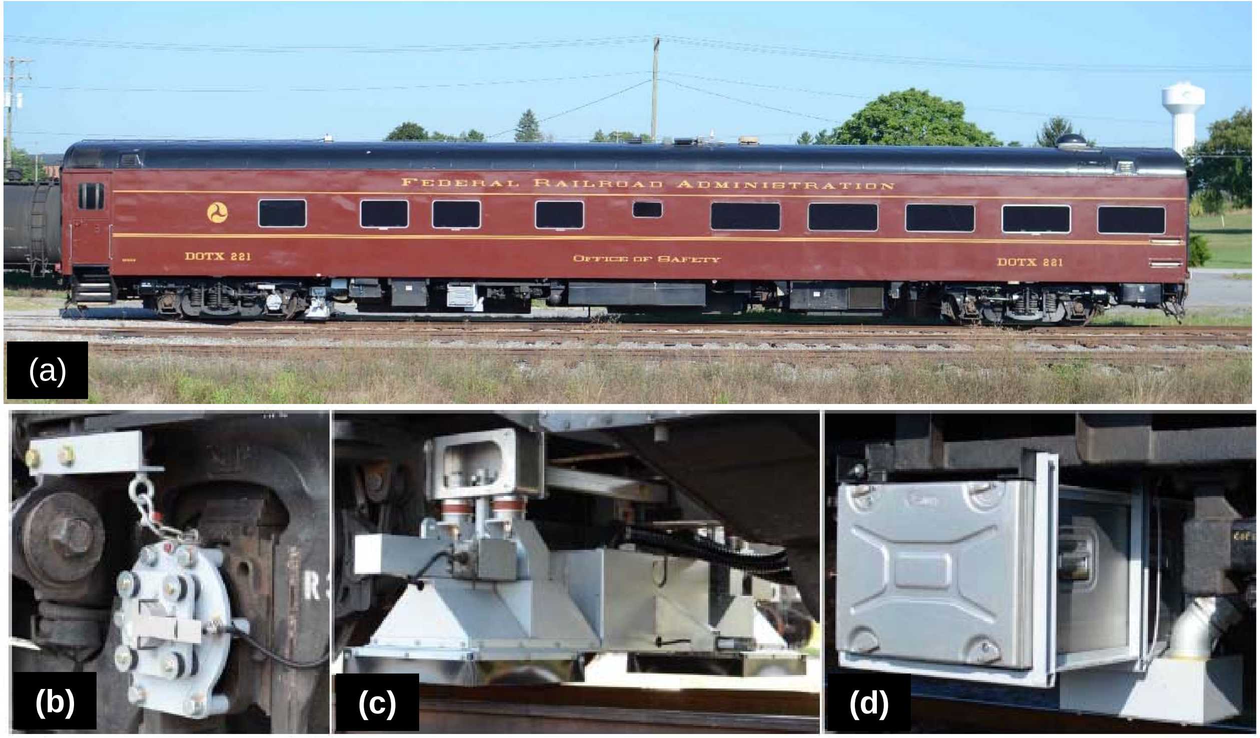
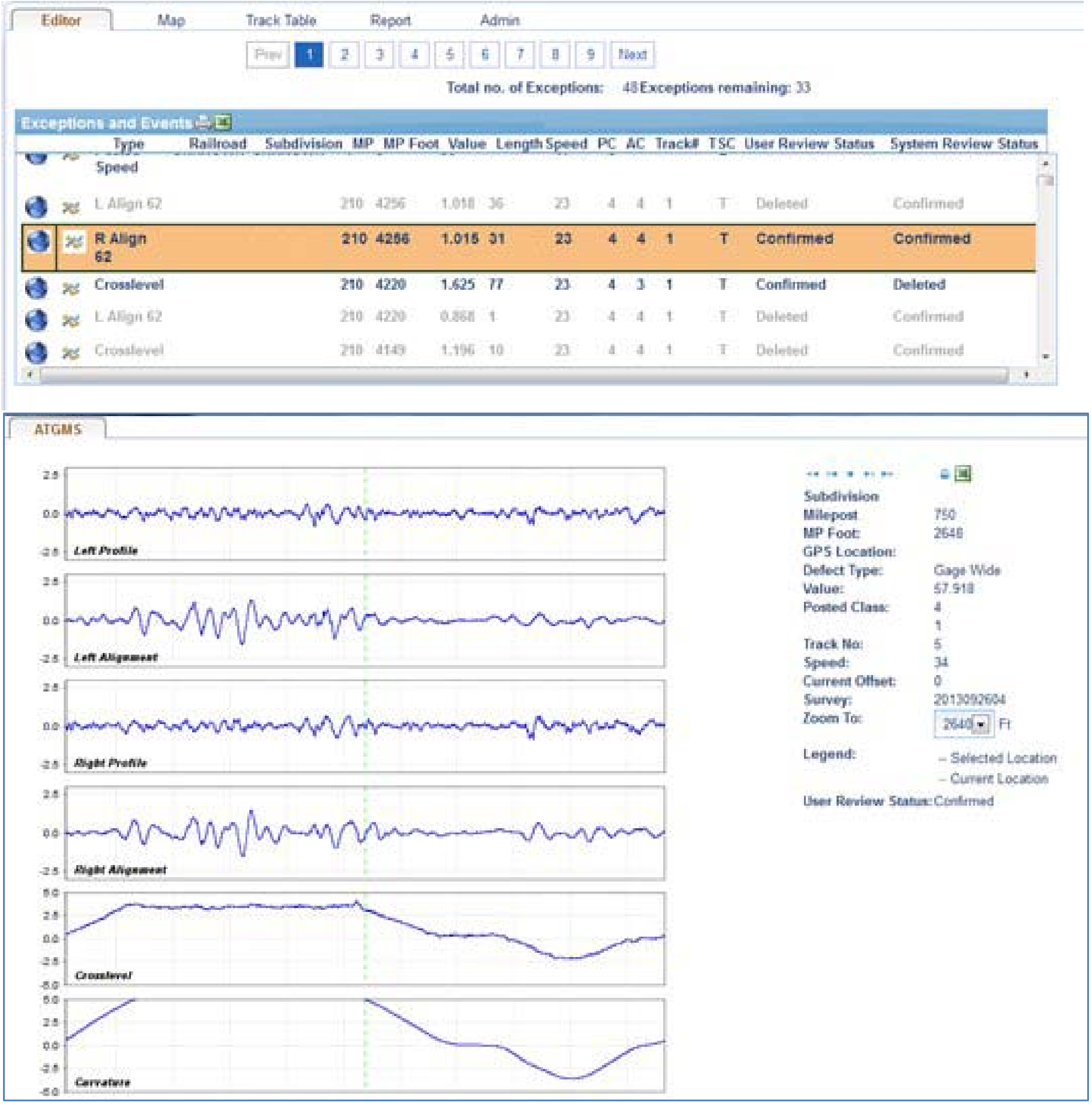


Figure 3. FRA's Truck-Mounted ATGMS on DOTX221 - (a) DOTX221, (b) Tachometer, (c) Measurement Beam, (d) Electronics Enclosure

Subsequent research efforts focused on developing and implementing the secure web-based Remote Editor Desk Console for near real-time review and validation of geometry exceptions as part of FRA’s data management and quality assurance processes. Examples of some of the displays available to the operator of the Remote Editor Desk Console are provided in Figure 4. This stage represented the foundation for the use of ATGMS by FRA’s Office of Safety that will be discussed in subsequent sections of this paper.



Total no. of Exceptions: 48 Exceptions remaining: 33

Type	Railroad	Subdivision	MP	MP Foot	Value	Length	Speed	PC	AC	Track#	TSC	User Review Status	System Review Status
Speed													
L Align 62			210	4256	1.018	36	23	4	4	1	T	Deleted	Confirmed
R Align 62			210	4256	1.018	31	23	4	4	1	T	Confirmed	Confirmed
Crosslevel			210	4220	1.625	77	23	4	3	1	T	Confirmed	Deleted
L Align 62			210	4220	0.868	1	23	4	4	1	T	Deleted	Confirmed
Crosslevel			210	4149	1.196	10	23	4	4	1	T	Deleted	Confirmed

Subdivision
Milepost: 750
MP Foot: 2648
GPS Location:
Defect Type: Gage Wide
Value: 57.918
Posted Class: 4
1
Track No: 5
Speed: 34
Current Offset: 0
Survey: 2013092604
Zoom To: 2640 Ft
User Review Status: Confirmed

Figure 4. Displays Available within Remote Editor Desk Console

Stage 3: Advancing Measurement Technology

The objective of this stage was to improve the technology to allow for a wider range of applications. As part of this effort, a carbody-mounted ATGMS was developed to minimize interference with truck and wheel set maintenance activities, better protect the measurement platform from flying debris and mud, and allow for installation of ATGMS on a wide range of vehicle designs with a lower installation and maintenance cost. During this stage, efforts focused on new sensor and processing algorithms to account for new measurement techniques that measured track from a location further away from the track. For demonstration and evaluation purposes, a carbody-mounted ATGMS was installed and operated on Amfleet I passenger car 82602 in Amtrak revenue service on the east coast between September 2012 and August 2013; the installation of the system is shown in Figure 5. Its performance was evaluated and compared to Amtrak's 10002 manned geometry inspection vehicle equipped with a truck-mounted geometry measurement system.

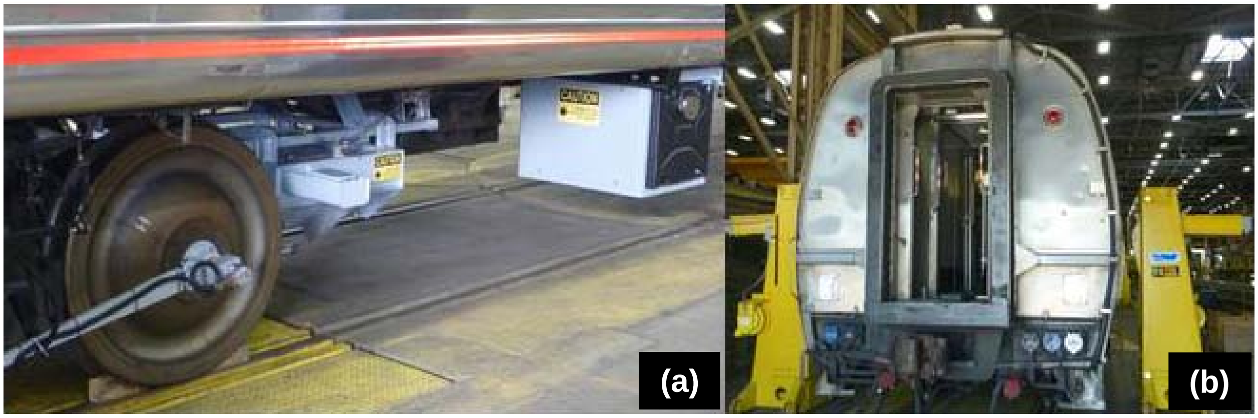


Figure 5. FRA's Carbody-Mounted ATGMS on Amtrak 82602 – (a) Tachometer, Measurement Beam and Electronics Enclosure, (b) GPS and Communication Antennae Installations

This testing demonstrated that the carbody-mounted ATGMS produced data of equal quality when compared with a truck-mounted track geometry measurement system. Differences between measured geometry data were within acceptable tolerances established for geometry measurements from multiple vehicles for this effort.

Stage 4: Development of Energy Harvesting Technology

The fourth stage conducted in 2011 and 2012 targeted development and evaluation of the technologies that allow for ATGMS to be deployed on freight vehicles and other rail cars without electrical power. Solar, wind, fuel cell, and fossil fuel power sources under different operational and environmental conditions such as vehicle speed and solar radiation values were assessed. This analysis identified the appropriate operating temperature range, mechanical, electrical, and safety requirements for the equipment to maximize use of the off-the-shelf components and facilitate future use of other secondary power sources such as fuel cells. Results of this analysis and historical data from solar power systems operated on railcars indicated that solar power can be effectively used as the primary source of power.

Stage 5: Future Demonstration of System in Freight Service

In the current development stage, FRA's approach to autonomous inspection technology will be demonstrated on freight vehicles operating under typical revenue service operations to establish the vision of the use of this technology for track assessment throughout the industry. Plans are underway to deploy the FRA carbody-mounted ATGMS on a typical box car for demonstration on short lines and regional railroads in early 2015. FRA's Office of Research, Development and Technology will arrange for an instrumented freight car to be deployed to volunteer railroads; following the traversing of the tracks designated by the participating railroad, results of the inspection will be provided to survey stakeholders through the same reporting mechanism employed by the FRA Office of Safety during Amtrak assessment surveys.

Technology and procedures developed by FRA throughout the first four stages of this program will be relied upon for the intended round of demonstrations. The survey vehicle will be equipped with an Electrical Power System that will employ both solar energy and direct methanol fuel cell technology as its primary and secondary sources of power for charging the ATGMS battery system. Charge controllers, the charger/inverter and the methanol fuel cells will communicate their status with the ATGMS system in a manner similar to other operational parameters communicated to operators through Alert and Alarm messages. A conceptual illustration of the instrumented vehicle is provided in Figure 6.

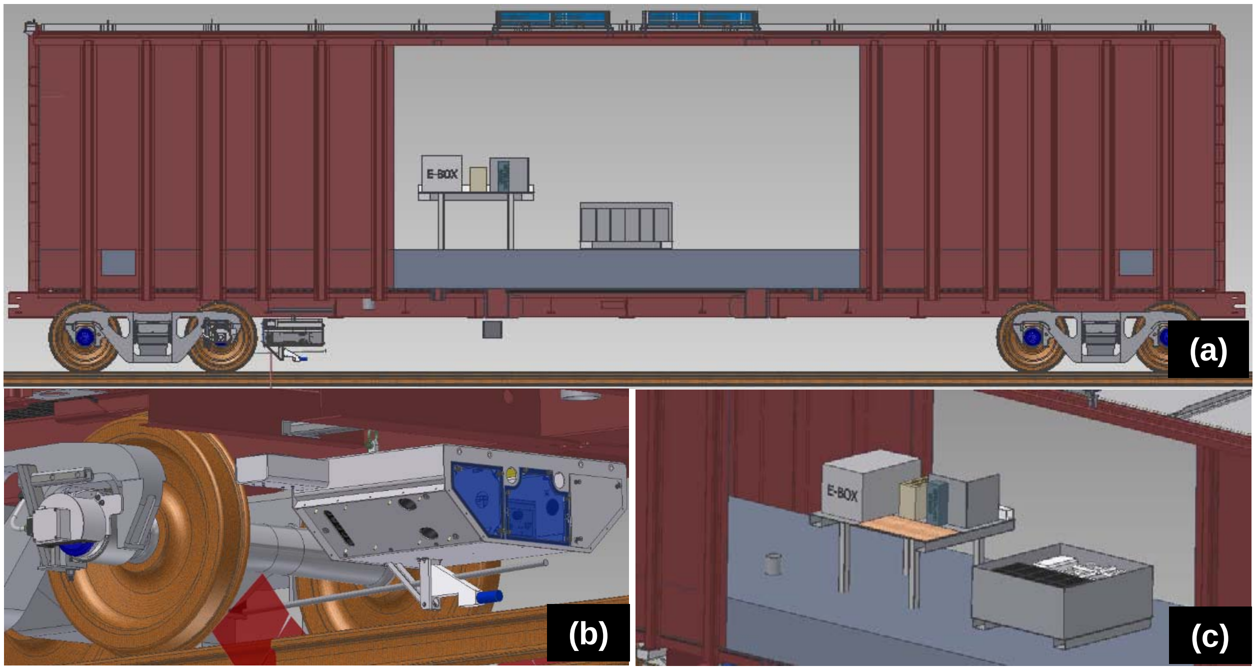


Figure 6. FRA's Carbody-Mounted ATGMS Concept on Freight Vehicle – (a) Freight Car, (b) Measurement Beam, (c) Internal Arrangement of Electronics and Electrical Power System Components

It is anticipated that demonstration of FRA's ATGMS in freight service will be completed in early 2015. FRA is preparing a research report on its ATGMS technology research program that is anticipated for publication in the fall of 2014.

FRA OFFICE OF SAFETY USE OF ATGMS TECHNOLOGY

Approach

Following FRA's long-term pilot study, the truck-mounted ATGMS was removed from its initial host vehicle and installed on FRA's DOTX221, a sleeper-lounge car, for use in Stage 2 development and evaluation under simulated revenue operations.

FRA's DOTX221 was operated in consist with ATIP's DOTX220 manned track geometry inspection vehicle over Amtrak passenger routes between September 2011 and June 2012. Comparison of geometry data collected with the autonomous and the manned geometry systems demonstrated that the two produced track geometry data of equal quality. To ensure the highest quality survey reports possible, the FRA developed and implemented the Remote Editor Desk, a secure web-based application used for near real-time review and validation of geometry exceptions prior to distribution to rail. Following the launch of the Remote Editor Desk, FRA began use of DOTX221 and its unmanned geometry system for non-compliance assessments of cross-country passenger routes.

During a typical unmanned, or remote, survey, sensor data recorded by the Data Collection Module is transmitted back to the Data Processing Sever and exceptions to the Track Safety Standards are identified and presented to users of the Remote Editor Desk for review. ATGMS data is then processed and distributed in a manner similar to that used on manned inspection vehicles. Exceptions to the Federal Track Safety Standards are automatically identified and displayed for quality assurance checks. Users of the Remote Desk Console verify data quality and track class identification as well as proper identification of track in multi-track territory. Resources available to the reviewers through the Remote Editor Desk include satellite imagery available through Google™ Maps and railroad-provided information such as track charts and time tables. Once all quality checks are completed, survey results are provided to survey stakeholders. Non-Compliant Exception Reports (NCERs) identifying track conditions that cannot support the current speed of the host train are immediately sent via email to FRA and railroad personnel. Track Assessment Reports (TARs) that summarize all events identified within a particular territory are distributed to FRA and railroad personnel at the end of each survey.

Through this approach, FRA is able to dramatically reduce operational costs. By placing the survey vehicle in a revenue service train, movement costs associated with a dedicated survey car are practically eliminated. In addition, staffing of the Remote Editing Desk Console requires fewer personnel than a typical manned survey car, reducing both labor costs as well as travel costs associated with traditional survey operations.

ATIP Operations with Unmanned Inspection Technology

FRA Office of Safety's initial use of the ATGMS-equipped DOTX221 on long distance passenger routes without an accompanying manned survey car started in Washington, DC, on July 29, 2013, and ended in Washington, DC, on September 29, 2013, covering more than 20,000 miles of track. A similar inspection campaign started on April 14, 2014, and ended on June 14, 2014, covering more than 21,000 miles of track. The second dedicated unmanned inspection survey applied many lessons learned from previous campaigns, resulting in better overall performance of the system from transmission of quality data from the Data Collection Module to delivery of the Track Assessment Reports to ATIP and railroad personnel. Data transfer worked as expected with no data loss in transmission or processing. Performance of the web-based Remote Editor Desk Console for information management and quality assurance met general expectations. Geometry exceptions reported were regularly field verified by railroad maintenance personnel. Additional modifications to the remote console are planned to improve efficiency and user experiences.

Quality Assurance

To achieve consistent and reliable measures of track geometry for manned survey operations, ATIP employs Quality Assurance/Quality Control (QC) procedures that meet the requirements of International Standards Organization (ISO) 17025 certification. Wherever possible, ATIP has applied these procedures to the unmanned assessment operations.

Standard maintenance practices used for manned inspection systems are employed with the unmanned equipment. Instrumentation verifications are conducted with the ATGMS equipment during scheduled maintenance visits to the car, while quarterly and annual system verification/calibration activities used for manned survey cars have been applied to ensure accuracy of the ATGMS equipment. Standard Operating Procedures (SOPs) established for the remote use of ATGMS technology have been developed that address operations and maintenance of the Data Collection Module on the vehicle as well as web-based Remote Desk Console. The QA, QC, and SOPs provide clear guidance for system operations and maintenance by experienced individuals, directions for immediate review of completed activities for accuracy and completeness, and documentation for decisions and remedial actions.

As part of the data quality assurance process, foot-by-foot geometry data collected on three selected track segments at different times during the July 2013 ATIP assessment were compared to evaluate the general consistency of geometry measurements. This evaluation data included two sets of geometry data collected on the same track between Los Angeles, CA, and Oakland, CA, on consecutive days; two sets of geometry data collected forty days apart on the same track between Memphis, TN, and New Orleans, LA; and two sets of geometry data collected nineteen days apart on the same track between Tempe, TX, and San Antonio, TX. Statistics of differences between the respective sets of collected geometry data on these track segments confirmed acceptable repeatability of the system throughout Amtrak assessment campaign.

Maintenance

Both vehicle and measurement system maintenance considerations were taken into account to determine appropriate scheduling of maintenance visits during the unmanned campaigns. Measurement system maintenance considerations include:

instrument verifications, inspection of measurement system component mounting hardware, archival of various data and diagnostic files stored on the remote computers, and the condition of the lenses on the optical gage system.

Engineering efforts to refine and improve on-board Data Collection Module components have increased reliability, accuracy, and mean time between maintenance actions of the system. During the April - June 2014 survey, the vehicle was only visited two times during the 34 days of the survey to perform minor system maintenance. Remedial actions were no more complicated than those required by a manned system for that same time period.

Lessons Learned

FRA Office of Safety has relied on its approach to remote unattended track geometry inspection for more than a year. Observations and takeaways from this experience, as well as those originating from the initial development and deployment of the technology can serve as important guides for the entire rail industry as various forms of autonomous track inspection is adopted:

- *Operational Costs and Efficiency* – It has long been anticipated that ATGMS technology would foster improved efficiencies and lower operational costs. These expectations appear to be well founded.

  Traditionally, inspection programs employing staffed inspection vehicles were able to survey close to 20,000 miles of Class I mainline track over the course of a calendar year. Employing unattended track inspection equipment on revenue service equipment in passenger service resulted in approximately twice as much track being surveyed in half the time.

  ATIP use of ATGMS technology has resulted in significant operational cost savings. Based on analysis of costs associated with passenger route assessments conducted in 2013, it is reasonable to expect on the order of 30 percent to 50 percent reduction in survey costs per mile when compared to more traditional inspection approaches. As the technology matures and operators develop optimized inspection strategies, these savings will likely increase.

- *Autonomous Instrumentation Check and Calibration* – Experience has shown that the equipment employed by ATIP has produced reliable data in a very stable fashion. The autonomous nature of this technology will only be enhanced with the development of reliable automatic, self-calibrating systems to minimize the need for manual instrumentation check and calibration activities.

- *Data Management* - The use of ATGMS or other autonomous inspection technology offers many benefits to the railroad industry, including high inspection frequencies, allowing for additional data availability for improved forecasting and trend analysis, and near instantaneous availability of data. This increase in data brings with it several challenges for the railroad, including issues with handling the increased volume of data resulting from higher inspection frequencies and the manner in which information collected with the system will be integrated into on-going inspection practices.

CONCLUSIONS

The FRA ATGMS development program has resulted in the demonstration of autonomous geometry measurement technology that can be deployed on range of standard rail vehicles, including freight cars, to collect and distribute continuous track geometry data accurately and reliably while running in standard revenue service. These demonstrations have not only illustrated advancements in geometry data collection but also the benefits of using autonomous track geometry measurement in regular operations. The transition of this technology to routine assessments conducted as part of FRA's ATIP in 2013 has shown that use of autonomous geometry inspection can result in significant reductions in operational costs, increased inspection coverage as well as frequency and virtually no impact on revenue service operations as compared to manned survey programs.

As with many technological advances, additional benefits can be realized through continued research and development. FRA has identified several technology areas for further improvement including methods for autonomous system calibration and advanced analysis methods to facilitate predictive maintenance as opposed to reactive maintenance. These advances, along with the completion of planned demonstrations to the freight rail community, are anticipated to accelerate the adoption of this technology throughout the rail industry.

As FRA's efforts to improve track safety and maintenance practices by enhancing conditional awareness through the use of autonomous inspection systems continues, it welcomes collaborative efforts with railroads that are willing to adopt autonomous technology and looks forward to supporting such initiatives.

ACKNOWLEDGMENTS

This paper presents the efforts of many people and organizations serving an ongoing effort to develop and promote autonomous track geometry measurement for widespread use in the railroad industry. The FRA's Office of Research, Development and Technology as well as its Office of Safety, particularly FRA's ATIP staff, spearheaded this effort in concert with ENSCO, Inc. of Springfield, Virginia. The authors would like to express their gratitude to Dr. Magdy El-Sibaie and Mr. Ali Tajaddini for their leadership and guidance during the early days of development.

The implementation of this technology could not have taken place in the manner in which it did without the essential logistical and in-kind support of both CSX Transportation and Amtrak who facilitated both short-term and long-term pilot studies at critical times within the research program. The authors would like to thank Ron Bright and Larry Biess of CSX as well as Paul Steets and Mike Trosino of Amtrak for their efforts to facilitate this important research.

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LIST OF FIGURES

Exhibit 4

Development of Autonomous Track Geometry Measurement Systems for Overall Track Assessment

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ABSTRACT

Since 1970 the use of automated track inspection systems have gone from limited use as a quality assurance tool by a handful of railroads to a key element to track asset management and safety assurance. Today some form of automated inspection for track geometry, rail profile and/or gage restraint measurement regularly used on most class one railroads. The data from these systems plays a key role in both safety assurance and maintenance planning. Over the last decade a new generation of autonomous track inspection systems has emerged, most recently exemplified by Autonomous Track Geometry Measurement Systems (ATGMS).

This paper summarizes the history of an ATGMS developed by the Federal Railroad Administration's Office of Research and Development. Lessons learned and experiences gained during a pilot study conducted on Amtrak's Auto Train route over CSX Transportation track will be provided. This paper will also describe a vision for the use of autonomous track geometry inspection in overall track condition assessment that will facilitate the identification of track-related issues before they reach levels associated with reportable defects.

INTRODUCTION

The number of track-caused derailments in the United States has decreased since the 1970s. This overall decrease can be attributed to many factors, including the development and improvement to the wide range of inspection technologies used throughout the industry. To further decrease the number of track-caused derailments, new methods of derailment prevention, including new track inspection methods, are needed. Improved track inspection methods can also provide benefits to railroad operations. In addition to reductions in-service track failures, improvements to inspection practices can lead to more efficient safety compliance programs, resulting in better use of resources and an increase in the capacity of the freight and passenger railroads.

Current methods for track inspection rely heavily on either visual inspection by track inspectors or automated inspection from dedicated inspection vehicles. Automated inspections, for the purposes of this discussion, are those in which key measurements are collected by instrumentation that is attended to and monitored by one or more operators. An inspection vehicle can be a self propelled or towed rail car or can be a hi-rail vehicle; in all cases, the inspection vehicle carries specialized equipment to measure various parameters associated with the track relying on trained operators to run the equipment and conduct the survey. Today, the use of automated track inspection systems has grown to become a key element to track asset management and safety assurance on all Class I US railroads and provides an objective method for the evaluation of track conditions that has contributed to the decrease in the derailments rates. However, methods involving automated inspections typically require scheduled track time, dedicated manpower resources and expensive systems. Emerging technologies relying on remote communication can significantly improve current methods.

Autonomous track inspection is a process in which the track is inspected from revenue trains using unattended instrumentation with minimal direct involvement from operators. Autonomous track inspection technologies have been developed utilizing revenue service trains equipped with data collection equipment that employs wireless communications to provide inspection data with dramatically increased frequency and reduced cost. Since 2000, systems of this nature have been used by Amtrak and

Class I freight railroads (*1*). By making inspection systems autonomous, data can be collected more frequently without track time being consumed by dedicated inspection vehicles. The use of autonomous inspection technologies will result in earlier detection of track defects and changes in maintenance practices from reactive to preventative, ultimately reducing the number of track caused derailments throughout the railroad industry.

The Federal Railroad Administration's (FRA's) Office of Railroad Policy & Development sponsors and conducts applied research as well as develops, tests, and evaluates technologies that support the FRA's core mission of improving rail safety and supporting national transportation policy. To that end, the FRA Office of Research and Development has undertaken a research program focused on the advancement of autonomous track geometry measurement to improve rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. This goal can be reached through the development of Autonomous Track Geometry Measurement Systems (ATGMS) that:

1. Reduce the life-cycle costs of geometry measurement operations;
2. Eliminate interference with revenue operations;
3. Increase inspection frequencies and productivity;
4. Provide data of the highest quality possible.

The FRA's research vision is to create a relatively low cost, self-powering geometry measurement system that can be deployed on standard rail equipment, including freight cars, to collect and distribute accurate track geometry data while running in a standard revenue train. The objective of the program is not necessarily to replace manned automated inspection systems as a quality assurance tool, but to create a more flexible, efficient tool for use in quality control and maintenance planning activities.

This paper will describe the FRA's ATGMS research program as well as its current development plan for this technology and provide a description of the challenges that must still be addressed to realize the vision for the use of autonomous inspection technology in assessing overall track conditions.

OVERVIEW OF FRA'S ATGMS RESEARCH

Development Plan

Although autonomous technology to evaluate track conditions is broadly accepted in the United States, the use of this technology to directly measure track geometry as part of regular maintenance and safety assurance practices is still in its early stages. Unattended systems that recorded track geometry data and downloaded recorded data to readers located at strategic points throughout a rail network have been utilized in Europe (*2*). Following the demonstration and implementation of autonomous track assessment systems on Amtrak and other Class I U.S. railroads, FRA took steps to develop and evaluate a track geometry measurement system that reported track issues in near real-time without the need for extensive dedicated data transfer mechanisms to be installed throughout a rail system.

To achieve the FRA's vision of relatively low cost, self-powering geometry measurement systems that can be deployed on standard rail equipment, a development plan has been created to guide the research and evaluation efforts. This plan is summarized as follows:

- *Stage 1: Long Term Pilot with Standard Inspection Technology* – The initial stage of development centers on the creation of a ruggedized, truck-mounted pilot system using commercial, off-the-shelf equipment to facilitate early evaluation. This activity would be used to develop the basic elements required for a system of this nature, including:
  - Communication software;
  - Processing software, including analysis tools, means to filter exceptions detected by the system that are usually addressed by operators in manned automated systems filtering, and system health monitoring;

  This phase employs a long term, pilot system test to facilitate the development of the elements cited above as well the evaluation of operational and maintenance issues that result from long term use of a system of this nature.

- *Stage 2: Simulation of Standard Revenue Operations* – Stage 2 focuses on the evaluation of the system under long distance, revenue service operating conditions. Refinements of hardware and software based on the results of pilot system testing accomplished under Stage 1 are also addressed. This phase of development will compare geometry data collected with the autonomous system to geometry data collected with typical manned geometry systems to identify and address any remaining issues affecting data captured by the autonomous system.
- *Stage 3: Advancing Measurement Technology* – Stage 3 involves the development of sensor technology to allow for installation of autonomous geometry measurement systems on wide range of vehicle designs to facilitate use under a wide range of operating scenarios. Efforts to be conducted during this activity include the development a full carbody-mounted system, improved sensors, non-contact speed measurement and revised processing algorithms to account for new measurement techniques. Movement of the system to the carbody offers several benefits to the ATGMS, including a less severe shock-and-vibration environment compared to truck- or axle-mounted systems, thus prolonging hardware and sensor service life; a location further away from the track, reducing exposure to mud, snow and flying ballast; and less manual interaction with the system during periodic truck maintenance activities. All of these benefits will serve to advance the ATGMS to a point where it can be deployed on a wider range of host vehicles where regular maintenance proves to be difficult. A key element of this stage of development will be the demonstration of this approach in revenue service operations and comparison of data to that collected by standard geometry systems.
- *Stage 4: Development of Energy Harvesting Technology* – Stage 4 targets the development and evaluation of technology that will allow autonomous systems of this nature to be deployed to cars without existing power sources, thus eliminating the restriction of installation of autonomous systems on powered cars such as passenger vehicles and locomotives. This effort involves the optimization of ATGMS power demands to facilitate advancement.

- *Stage 5: Demonstration of System in Freight Service* – As the issues addressed in the earlier development stages are solved, this technology will need to be demonstrated on freight vehicles operating under typical revenue service operations to establish the vision of the use of this technology for track assessment throughout the industry.

As is the case with the introduction of any new technology, implementation issues must be identified and challenges must be addressed by both operators and regulators if the technology is to have an impact. Therefore, FRA has relied on partnerships with railroads to facilitate this research to date and continues to seek railroad participation in continuing research activities.

Technical Approach

Developed on behalf of the FRA by ENSCO, the ATGMS is designed to detect, locate, and report potential track defects in near real-time to a web-based inspection data management system for review and remedial action. Although the confirmation of defects on the ground and remedial actions still require human intervention, autonomous track inspection provides a significant step forward in maintaining track by increasing the frequency and decreasing the cost of track inspection. The core technologies and approach employed in the ATGMS, as illustrated in Figure 1, includes three major components - an onboard unit, processing servers and a cellular communication link.

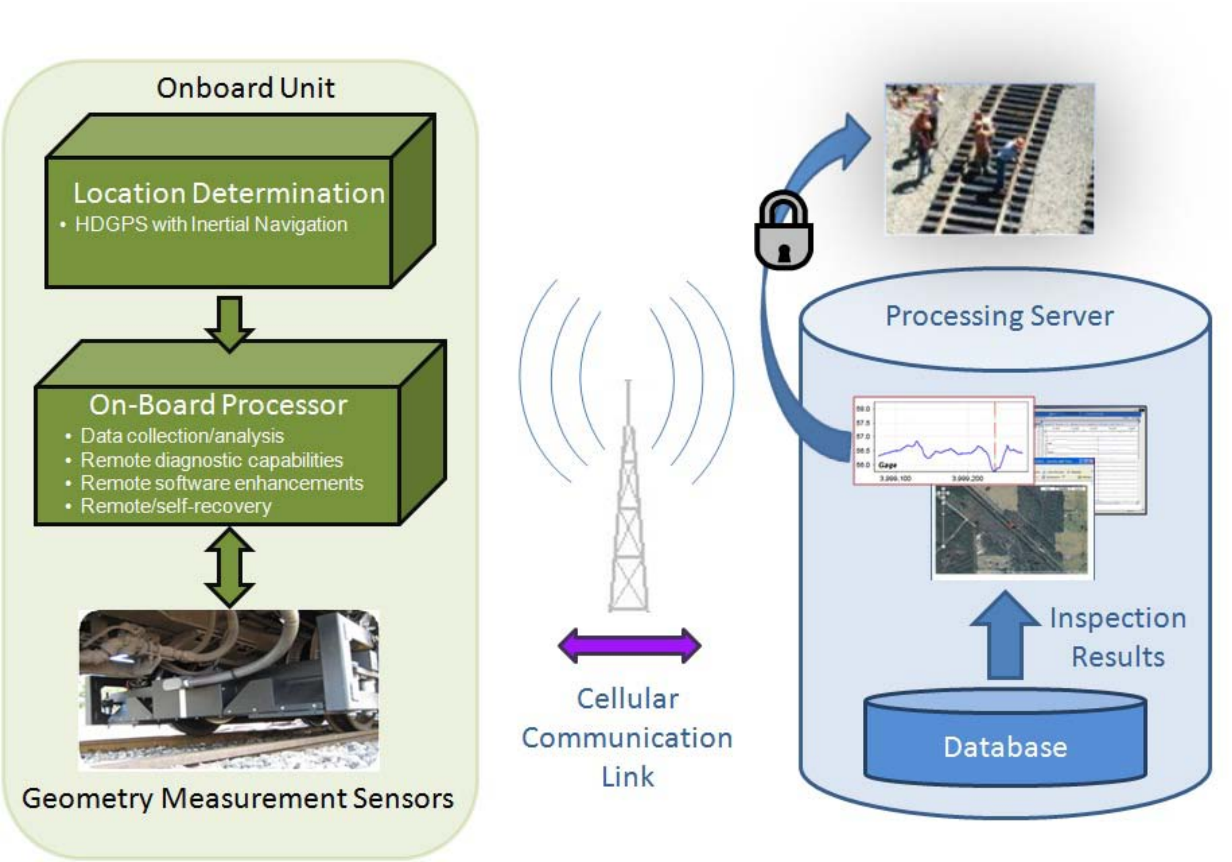


Figure 1. General Depiction of FRA's ATGMS Installation and Web-Based Reporting Application

- *Onboard Unit* – The portion of the system located on the vehicle consists of a series of measurement sensors, a computing platform, and location determination technology.

  A dramatic increase in computer power and reliability, combined with a decrease in processor size, is one of the enabling factors for autonomous monitoring. Onboard equipment has become small enough, reliable enough, and sophisticated enough to conduct most of the operations currently performed by inspection car operators. These operations include recognition of issues with instrumentation, location marking, and exception identification. Although there are still operations where it is difficult to replace a human operator, particularly in exception evaluation, when something malfunctions or unexpected situations arise, these situations can be identified and handled appropriately within the overall system in an automated fashion.

Global Positioning System (GPS) technologies are critical to autonomous inspection in that they provide location of the detected defects in absence of an operator. Onboard GPS based location systems can have different levels of accuracy and sophistication from regular GPS receivers to Differential GPS (DGPS) to high end DGPS assisted inertial navigation systems. As a result of early evaluations, the ATGMS installed on the Auto Train employs DGPS assisted inertial navigation systems for providing location information. This approach offers the benefit of correcting the shortcomings of standard GPS such as decreased accuracy due to atmospheric conditions and the blockage of signals due to local terrain, dense foliage, overpass bridges, tall buildings and other obstructions. It should be noted, however, that this increased accuracy, which can be as high as 1 foot, comes at a cost in that it is achieved by using more expensive hardware and paying for differential correction services.

- *Processing Servers* – A key element of the autonomous inspection system is a central server to which data is transferred. This facility features data processing capabilities, a database management system, and Geographic Information Systems (GIS) applications to facilitate reporting of areas of interest.

  The nature of autonomous inspection systems greatly improves the productivity of inspection operations but can increase the volume of data to be considered. An efficient data management and reporting system is necessary to create uniform data storage and maximize the effectiveness of reporting track issues. GPS coordinates or other location data associated with defects are not sufficient unless there are underlying maps that show information associated with track and other rail infrastructure. This allows for conversion of location data reported by the onboard autonomous systems into standard linear railroad referencing (subdivision, MP, FT, track number). With the impending implementation of Positive Train Control (PTC) in the United States, the accuracies associated with the location of rail infrastructure are expected to increase to a level where track number can be correctly determined. The centralized approach to data processing and reporting will be able to leverage this improvement in accuracies to the advantage of automated inspection technology.

- *Cellular Communication Link* – The manner in which data is transferred between the onboard units, the central processing servers, and the data recipients is an important feature of any autonomous inspection system. It affects the way in which measured data is uploaded to the central processing servers, and processed information is distributed to inspectors or maintenance personnel.

  Cellular communication is a critical enabling technology used for retrieval of data from the onboard systems and providing remote monitoring and maintenances to the systems. The FRA ATGMS uses publicly available commercial data networks. The bandwidth of available wireless communications continues to increase providing opportunities to collect and upload larger data sets, a key consideration for future enhancements of autonomous inspection technology.

  Data collected by the ATGMS can be made available to stakeholders through a variety of ways including email alerts, electronic reports and dedicated websites and presentation of survey results to outside railroad data management and reporting systems. Figure 2 illustrates the various reporting tools that are made available through the ATGMS-dedicated website.

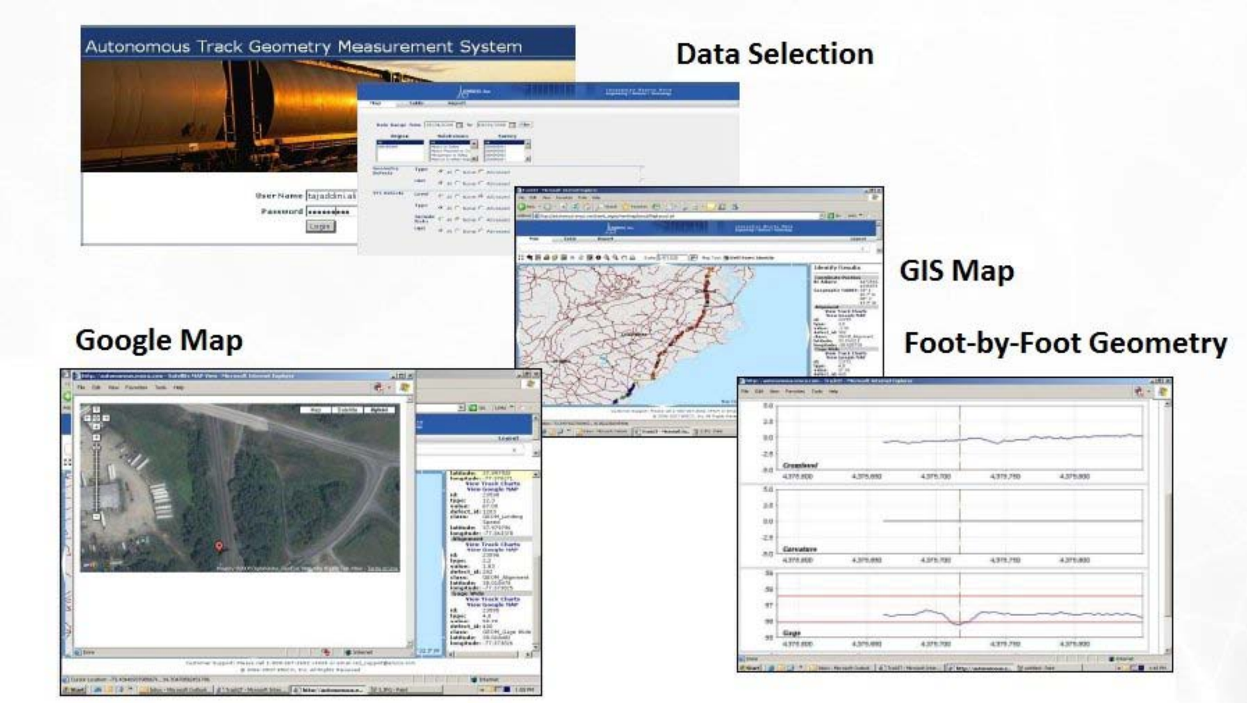


Figure 2. Illustration of Reporting Mechanisms within FRA's ATGMS

ACCOMPLISHMENTS TO DATE (STAGE 1 DEVELOPMENT)

The FRA commenced a pilot program in 2008 involving the use of an Autonomous Track Geometry Measurement System (ATGMS) on Amtrak's Auto Train operating between Virginia and Florida on CSX Transportation track to evaluate such implementation issues. The FRA's ATGMS, the instrumentation beam of which is pictured in Figure 3, was installed on an Amtrak Superliner II sleeper car in January 2008 and introduced into revenue service on Amtrak's Auto Train service immediately following installation. Amtrak's Auto Train runs daily on CSX-owned track between Lorton, VA, near Washington, DC, and Sanford, FL, a distance of 855 miles. From the time of its initial use until its removal in March 2011, the FRA's ATGMS unit surveyed close to 460,000 miles of track, an average of approximately 153,000 miles per year.

Figure 3. FRA ATGMS Installation on Amtrak Superliner II in Auto Train Service

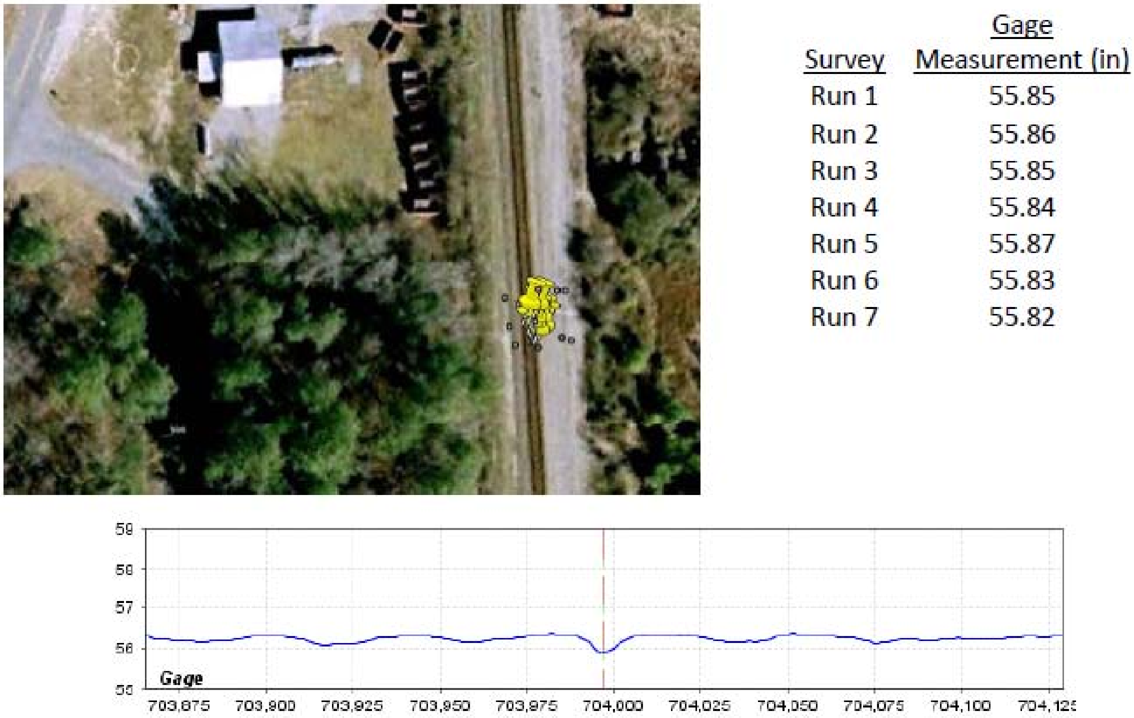
The efforts under the pilot program employing the prototype ATGMS produced several key results that show that this is a viable technology for long-term use in service within the US rail industry. These results are highlighted by the following:

- *Repeatability* – The initial effort demonstrated that the prototype ATGMS was capable of producing repeatable data over time, a key aspect to the reliability of the system and its data products.

  During the initial stages of deployment, the foot-by-foot data collected and stored on the ATGMS for evaluation purposes was compared to foot-by-foot geometry measurements collected by an FRA-owned automated track inspection car over the same territory. Comparisons of the results collected by both systems over selected evaluation zones met reproducibility standards used to confirm the proper operation of track geometry measurement systems on a single platform.

  Repeatable data was a critical aspect of the implementation of the pilot program with CSX. Under the implementation of the initial effort, potential track defects identified for follow-up inspection by CSX would have to be shown to be repeated over several consecutive surveys before deploying field personnel; the subject of identification of track issues through repeated detection is an issue to be addressed later in this paper. Defects that were believed to be an imminent threat for derailment were brought to the railroad's attention immediately.

An example of the type of report created through use of the ATGMS is illustrated in Figure 4. In this example a narrow gage exception was repeatedly measured at the same location over several consecutive runs made in the same month in late 2010. These measurements were assessed for data quality using a method described later in this section and reported to the railroad.



Survey	Gage Measurement (in)
Run 1	55.85
Run 2	55.86
Run 3	55.85
Run 4	55.84
Run 5	55.87
Run 6	55.83
Run 7	55.82

Figure 4. Example of Repeated Narrow Gage Measurement Reported Through Use of FRA's ATGMS, Fall 2010

- *Automatic Data Filtering* – The FRA ATGMS processes the measured geometry data on the vehicle and provides notification of detected track issues from the instrumented car in near real-time. It was recognized early in the development of the ATGMS that one of railroad industry's biggest concerns regarding autonomous geometry measurement was the possibility of a large number of false alarms that would cause the track to be slow ordered when in fact these are no defects.

The subject of automatic data filtering has been focused on throughout the development of the ATGMS. A unique system capable of automatic data editing to remove false exceptions has been developed to address the reliability of results provided by this unattended system. The editing process relies on a proprietary set of software modules to determine the location of the detected event, verify that the measurement in question is valid and make the result available for display and notification. Using the experiences from decades of track geometry data collection and years of developing autonomous track assessment systems, an approach for data validation was developed that employs two algorithms to ensure data integrity. The first is a human-trained decision model, a self-teaching intelligent algorithm that recognizes the patterns associated with the actual experience of human data editors and applies those patterns to potential measured defects. Edited data from thousands of miles of actual survey are used to “teach” the program how to filter out false exceptions. The second is a computational signature analysis algorithm that analyzes frequency components of the measured signals to identify those cases that exhibit higher-frequency components not related to track-geometry that would cause the reported geometry measurement to be questioned.

This two-pronged approach to exception editing has been shown to be effective in removing instances in which certain conditions in the data look like there are defects present when in fact there are none. Examples of the type of reported data that the system is capable of filtering out include signals suffering from dirty measurement optics, gage conditions found at diamond frogs and turnouts as well as profile irregularities that can be observed in crossovers. The two algorithms are continually undergoing evaluation for accuracy. Recent analysis conducted on a set of geometry exceptions identified by the on-board unit on the Auto Train route over many runs indicated that the experienced human operator agreed with results of the automatic data processing algorithms in both the acceptance of valid exceptions and the rejection of invalid exceptions over ninety percent of the time. It is recognized that these results may be dependent on track features specific to the route over which the system has been employed to date. The flexible architecture of the editing approach provides for continual updates to improve accuracies as the ATGMS gains additional miles and use throughout the rail industry. This approach to filtering will yield the added benefit of assuring consistency of track assessment by minimizing the impact of individual operator judgment of track issues that can affect automated track inspections.

- *System Reliability* – Maintenance, repair and system reliability are critical aspects of the ATGMS that will have a direct bearing on its use by the rail industry. It is important that the system have a high mean time between failures since the system is unmanned and the intervals between maintenance cycles must be as long as possible.

  The design of the FRA's ATGMS features critical elements and sensors that have been used either in autonomous technology deployments or in traditional track geometry measurement systems over extended periods of time. To insure safety and long service life, the design features redundant mechanical mounting systems, shock and vibration protection, internal diagnostics, and ruggedized electronics.

  During the time over which the FRA's ATGMS was running, the system experienced two failures that could be termed critical to the system:

  - One (1) tachometer failure due to issues with fabrication of the mechanical mounting used to attach the sensor to the end of the axle that lead to failure of the mounting bracket. The design of the mounting bracket was changed and system inspection procedures were modified to monitor the condition of this component. No repeat of this issue has been observed.

  - One (1) laser head sensor used to measure the position of the rails in space suffered from poor performance due to the condensation within the laser enclosure. The manufacturer of the laser head sensor has addressed this issue for subsequent deployments.

  Aside from some of the typical troubleshooting that accompanies the deployment of manned geometry measurement systems and the two issues highlighted above, the FRA's ATGMS was found to be reliable over the deployment of the system. None of the issues cited above can be attributed to the autonomous nature of the system. The system relies on digital sensor technology for track geometry measurements, eliminating the need for daily calibrations required to address drift in analog sensors. Where reliance on digital sensors is not possible, namely the tachometer located on the end of one of the axles, self-calibration procedures have been implemented to extend the time between system calibrations.

A key aspect of the ATGMS is keeping lenses used in optical sensors clean from dirt and debris to maximize the quality of the data. The FRA ATGMS employed a film-based optic protection system. This approach was shown to be effective, but changes can be made to improve the logic used the advance the film to maximize film service life and the ease at which those changes can be made. These changes are planned for future deployments.

Plans are in place for improving system reliability through the enhancement of health monitoring features deployed within the system. The number of internal checks will be increased and automatically monitored and interrogated in order to provide a more comprehensive look at system health and data quality than was done with the prototype system. In future deployments, reports summarizing any detected system issue will be emailed to key personnel so that the overall operation of the system can be monitored and corrected if required.

CONTINUING DEVELOPMENT OF ATGMS

Current Activities

The removal of the ATGMS from Auto Train service represented the end of Stage 1 development and activities are under way for Stages 2 and 3. A summary of these activities are as follows:

- *Stage 2 Development* – In August 2011, the FRA's prototype system was transferred to DOTX 221, a passenger car employed within the FRA's Automated Track Inspection Program. The system will be run in parallel with the FRA's DOTX 220 inspection vehicle to allow for comparison of geometry data collected with the autonomous system to geometry data collected with a typical manned geometry system over a wide range of track conditions for evaluation purposes and additional system development.

One of the main benefits of increased inspection frequencies is the ability for railroads to monitor changing track conditions and identifying issues prior to reaching levels that could lead to track-caused derailments. The vision for ATGMS is one in which railroads deploy multiple unattended systems throughout their network to capture track information during routine movements of revenue service equipment. When used in this fashion, ATGMS must be able to collect, process and deliver overall information on track condition to provide information necessary for detailed trending and degradation analysis. In addition, ATGMS must have the ability to "drill-down" on a section by section basis to allow for observation/reporting on track changes over time as well as the ability to have trending information determined in an automated fashion and delivered to users in a proactive fashion to facilitate preventative action, not reactive action. To realize this vision, FRA will be implementing the following features during Stage 2 development:

- Ability to report track geometry through transmission of "foot-by-foot" data; this feature represents a departure from the current operating scenario in which only exceptions to pre-defined thresholds are communicated in near real-time. ATGMS will maintain the ability to report track exceptions as soon as they are identified;
- The means to automatically conduct reliable and accurate degradation assessments over track that has been traversed during multiple surveys. Results of such degradation analyses will then be able to be reported to project stakeholders for remedial action in a proactive manner;

- *Stage 3 Development* – In early 2012, FRA plans to deploy a carbody-mounted ATGMS on a typical Amtrak Amfleet car for initial use on the Northeast Corridor. The carbody mounted ATGMS, a concept of which is illustrated in Figure 5, looks to provide the industry a lower cost system design that is more portable, encouraging railroads to consider moving systems of this nature to a variety of vehicles to maximize the extent of degradation analyses. During this stage, the effectiveness of degradation analyses and comparison of measurements collected with the carbody mounted system and traditional manned inspection systems mounted to trucks will be evaluated.

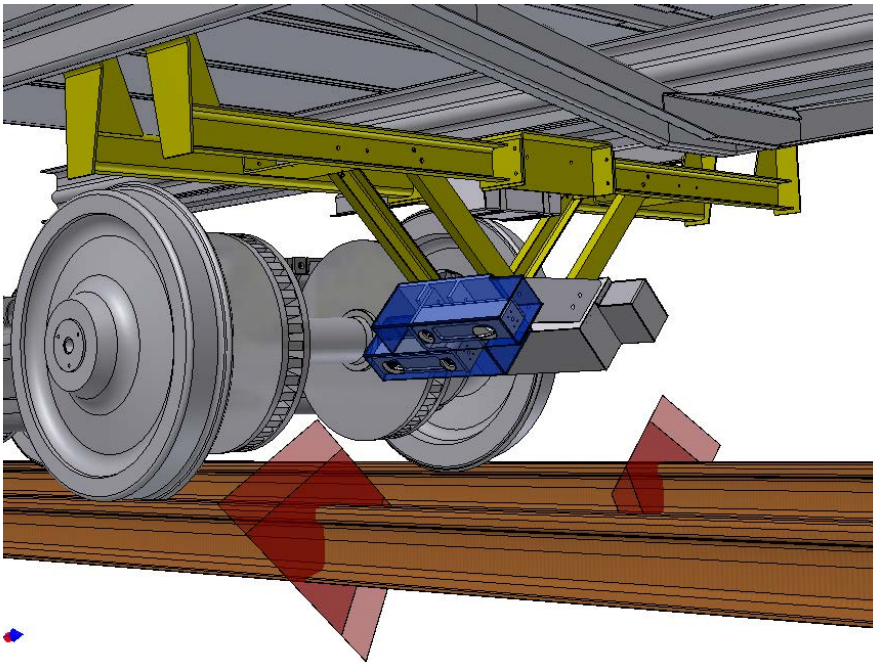


Figure 5. Early Concept for Carbody Mounted ATGMS for Initial Deployment on Amtrak Passenger Equipment

FRA intends to follow Stage 3 development efforts with demonstrations of fully autonomous inspection systems in freight service and is actively looking for industry participants in this next stage of development.

Technical Challenges

As the FRA ATGMS moves from Stage 1 development into Stages 2 and 3, several technical challenges remain:

- *Automatic Data Filtering* – As cited earlier, automatic data filtering was a major focus of Stage 1 development. It is considered to be a critical aspect of the system for industry acceptance. Even with the encouraging results generated in the pilot program, it is realized that track features specific to the route over which the system has been evaluated may have an influence on data filtering results. As ATGMS units are run during follow-on demonstrations and evaluations, the creation of efficient and reliable automatic data filtering will continue to be a target for improvement.

- *Location Determination* – A critical aspect to the reporting of suspected track defects, as well as track degradation assessment, is the accurate identification and referencing of track location. Even with use of high accuracy GPS information available in the ATGMS, referencing these track issues with respect to railroad specific features such as Track Number, Track Class, etc., within a given territory presents many challenges. This can be accomplished with the use of highly accurate geo-referenced base maps, which are being developed within the rail industry to meet the needs of Positive Train Control deployments. However, there are many areas throughout the country that this information is not available for at this time and information that does exist is not generally shared for research purposes. FRA is currently assessing methods that can be used to establish specific track location information from existing geo-referenced location information in order facilitate data processing and accurate location reporting in the most efficient manner possible. Whether this detailed geo-reference information is provided via new methods or this information is provided by research partners in the railroad industry, this information will be vital to the accurate identification of location and track class associated with track issues to aide users in taking remedial actions and conducting compliance analyses, as well as degradation analyses, on surveyed track.
- *Data Accuracy Associated with New Technology* – As cited earlier, Stage 3 development will focus on driving technology upon which ATGMS is based towards lower cost and greater portability. As this initiative is undertaken, great care and due diligence must be given to ensuring that sensors, mounting arrangements and other critical elements of the approach result in the same level of data accuracy and reliability as is present with traditional manned automated geometry measurement systems.

- *Energy Harvesting Technology* – To achieve the vision for ATGMS, a system of this nature should be deployable to a wide range of vehicles, including freight cars with no pre-existing means of providing power to the system. To date, the deployment of autonomous inspection technology intended for long-term use has been on cars or locomotives with available power. The FRA is currently evaluating concepts for energy harvesting technologies that can be used in conjunction with an autonomous system that will provide sufficient power for continuous operations for extended periods of service. At this time, it is envisioned that a combination of several approaches, including but not limited to solar, motion generated and wind energy harvesting will all play a part in the Stage 4 development that is crucial for widespread deployment of autonomous inspection technology.

Procedural Challenges

Operational issues must be addressed by both potential users and regulators for the introduction of new technology to be successful. Based on lessons learned through the pilot program conducted in Stage 1 development and by railroads that have implemented other autonomous inspection systems, clear maintenance and operational procedures must be established by an operator prior to deployment of an autonomous inspection system. Procedures should be developed for the autonomous system itself to clearly establish the roles of railroad personnel in performing maintenance and calibration activities and safety precautions must be established when lasers (as in the case of the ATGMS) or high voltages are associated with the inspection system. In addition, operational instructions must be created to address any situation in which the inspection system interferes with the operation of systems on the vehicle or the vehicle itself. These considerations, however, are not felt to be major challenges to the use of this technology.

Several key procedural issues associated with the introduction of autonomous track geometry inspection technology remain that still require effort to address:

- *Data Management and Remedial Actions* - The use of ATGMS or other autonomous inspection technology offers many benefits to the railroad industry, including high inspection frequencies, allowing for additional data availability for improved forecasting and trend analysis, and near instantaneous availability of data. This increase in data brings with it several challenges for the railroad, including:
  - The increased volume of data resulting from increased inspection frequencies;
  - The manner in which information collected with the system will be integrated into on-going inspection practices;
  - Validation of events identified by the system given the increased frequency in which data is reported.

Prior to the implementation of ATGMS, a railroad needs to have a clear plan on data usage. As is often done in automated inspection programs, different thresholds are used to identify issues that could grow into exceptions. With increased reporting frequencies, new thresholds may be warranted to identify and monitor issues at earlier stages of development. As was considered with the pilot program discussed here, pilot applications can afford an opportunity for operators to gradually develop response plans, formulate appropriate thresholds where applicable, and grow accustomed to data flow rates. Based on past experience, pilot applications on limited routes can be useful to identify issues and validate the results of the system while minimizing railroad investments.

Confidence in the data reported with this technology can often be bolstered by considering the existence of “repeated events” on consecutive surveys as a validation mechanism. This approach was used in the pilot program conducted under Stage 1 development. Although this represents a logical approach during the initial stages of autonomous inspection deployment, the “awareness” of a potential issue without immediate follow-up action represents a risk. This is an extremely critical issue; it represents the potential for increased liability for the railroad and poses a regulatory issue as well.

- *Regulatory Issues* – Current safety rules were developed based on inspection practices employing visual inspections and automated inspections conducted at intervals that could be considered infrequent when compared to those achievable with autonomous inspection systems. As ATGMS is used as a tool in a quality control process and track degradation is monitored, established practices may need to be reconsidered.

  FRA has acknowledged that current practices and regulations may actually provide a disincentive for implementation of autonomous technology. With an increase in inspection frequency, railroads may be alerted to potential defects with great regularity, and follow-up inspections may prove costly and logistically difficult prior to the next train. Overall improvement in safety due to increased inspection frequency may justify a relief on reaction time or allowance for additional means of validation. A potential solution posed by FRA could involve re-evaluation of appropriate railroad response time and/or action to particular exceptions reported with an autonomous inspection system (*1*).

FRA and the railroad industry must work together to develop long-term strategic plans for implementation and use of this technology. FRA continues to work with railroad partners through the various stages of the ATGMS development to address usage issues so that this type of technology can be used to enhance safety and improve maintenance planning with measurable results.

CLOSING THOUGHTS

The continued development and demonstration of autonomous track geometry inspection technologies is critical to improving efficiency and reducing the number of track caused derailments throughout the railroad industry. FRA looks forward to working with railroad industry members interested in participating in pilot programs or in establishing their own programs centered about this maturing technology to realize the vision of a system for use in quality control and maintenance planning activities.

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LIST OF FIGURES

Exhibit 5

Autonomous Track Inspection Systems – Today and Tomorrow

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ABSTRACT

Since 1970, automated track inspection systems have gone from limited use as a quality assurance tool by a few railroads to a key element to track asset management and safety assurance. Today, some form of automated inspection for track geometry, rail profile and/or gage restraint measurement regularly is used on most Class I US railroads. The data from these systems plays a key role in both safety assurance and maintenance planning. Over the last decade, a new generation of autonomous automated track inspection systems has emerged. These include Vehicle/Track Interaction (V/TI) Measurement systems and more recently Autonomous Track Geometry Measurement Systems (ATGMS). There are three critical phases in the introduction of any new technology into the railroad track inspection arena - technology development, recommended practices for acquisition and use of the data, and regulatory reform to allow for and promote the benefits of the technology insertion. This paper briefly reviews the history of autonomous track inspection systems, describes the current state of the art, and provides an initial "roadmap" for the railroad community to use in developing and implementing plans and programs to take full advantage of this emerging technology for the benefit of safety and performance.

INTRODUCTION

The number of track caused derailments in the United States has been gradually decreasing since the 1970s, but the rate of the decrease is slowing down. New methods of derailment prevention, including new track inspection methods, are needed to drive the number of derailments down further. In addition to safety considerations, the new track inspection methods can have operational benefits. They can help to reduce in-service track failures, therefore helping to maximize the capacity of the freight and passenger railroads.

Current methods for track inspection include either visual inspection by track inspectors or automated inspection from dedicated inspection cars. In this context, automated inspections are those in which key measurements are collected by instrumentation that is attended to by one or more operators. An inspection car can be self propelled, towed or can be a hi-rail vehicle, but in all cases it is a dedicated car carrying specialized equipment to measure the track with trained operators to run the equipment and conduct the inspection. Since the 1970s, the use of automated track inspection systems has grown to become a key element to track asset management and safety assurance. Today, some form of automated inspection for track geometry, rail profile and/or gage restraint measurement is regularly used on all Class I US railroads. Automated inspection has provided an objective method for the evaluation of track conditions that has contributed to the decrease in the derailments rates. However, methods involving automated inspections typically require track time, expensive systems and dedicated manpower. New emerging technologies can significantly improve current methods.

Autonomous track inspection is a process of inspecting the track from revenue trains using unattended instrumentation with minimal direct involvement. New autonomous track inspection technologies have been developed utilizing revenue service trains equipped with data collection equipment that employs wireless communications to provide inspection data with dramatically increased frequency and reduced cost. This type of technology will have significant ramifications on the nature of track inspections, maintenance practices, and government regulations. By making inspection systems autonomous, the data can be collected more frequently without consuming track time. The use of autonomous inspection technologies will result in earlier detection of track defects and changes in maintenance practices from reactive to preventative, ultimately reducing the number of track caused derailments throughout the railroad industry.

This paper will provide a brief background on autonomous track inspection systems and technologies, describe their uses to date, and discuss multiple issues and ramifications associated with their implementation. An initial "roadmap" for the railroad community to use in developing and implementing plans and programs that take advantage of this emerging technology will also be provided.

BACKGROUND

Implementation of Autonomous Track Inspection Technology to Date

The first systematic use of autonomous track evaluation in the United States took place on the Acela trainsets, the high-speed trainsets operated by the National Passenger Railroad Administration (Amtrak) on the Northeast Corridor (NEC). Amtrak's implementation of autonomous technology was in response to Federal Railroad Administration (FRA) regulations.

In 1998, the FRA introduced Subpart G of the Track Safety Standards that addressed passenger train operation at speeds above 90 MPH in Track Classes 6 through 9 [1]. 49 Code of Federal Regulations (CFR) 213.333 required daily monitoring of car body and truck frame accelerations onboard equipment operating at speeds in excess of 125 MPH. To satisfy this requirement, Amtrak equipped its Acela high-speed train sets with Autonomous Ride Monitoring Systems (ARMS) in 2000; the concept of the ARMS is illustrated in Figure 1. The ARMS units are based on technology developed by the FRA Office of Research and Development and ENSCO, Inc. The systems allow remote, autonomous monitoring of performance of the Acela train sets from a vehicle/track interaction perspective through the measurement of car body and truck accelerations. The acceleration data is used to evaluate rough riding locations and/or poor performing train sets and report incidents to a response team for corrective actions. A typical installation of the Amtrak ARMS system is pictured in Figure 2. Amtrak's systems have been in operation for nine years, and the data provided by these systems is used daily by Amtrak maintenance forces and management personnel to ensure the safety and quality of Amtrak's high-speed service. In 2002, Maryland Transit Administration's MARC commuter service followed Amtrak's lead and equipped a number of their trains with similar systems.

In 2004, the Union Pacific Railroad became the first freight railroad in the United States to adopt technology of this nature. Application of the technology employed by Amtrak and MARC was augmented by the use of axle-mounted accelerometers to identify battered joints, misaligned switches, damaged frogs and other high-impact events. Currently 200 autonomous systems targeting vehicle/track interactions are used across the Class I US railroads with the data from the systems being fed into railroad maintenance planning processed on daily basis.

The experience of Amtrak and the other Class I US railroads illustrated the effectiveness of autonomously monitoring potentially dangerous track conditions causing undesirable vehicle responses. Several parties have taken steps to build upon this success by developing autonomous track geometry measurement systems. In 2004, ImageMap developed its Unattended Track Geometry Measurement System (UTGMS) and installed it on several revenue trains in the United Kingdom. In 2008, the FRA installed the Autonomous Track Geometry Measurement System (ATGMS), developed on behalf of the FRA by ENSCO, on Amtrak's Auto Train operating between Virginia and Florida. The ATGMS detects, locates, and reports potential track defects in near real-time to a web-based inspection data management system for review and remedial action. The principle behind the FRA's ATGMS is shown in Figure 3.

While use of autonomous technology to evaluate track conditions is broadly accepted in the United States, the use of autonomous technology to directly measure track geometry as part of regular maintenance and safety assurance practices is still in its infancy. Although the ATGMS and UTGMS handle data collection and processing differently, they both fulfill the objective of the technology – inspecting the track from revenue trains using unattended equipment without operators. Although the confirmation of defects on the ground and remedial actions still require human intervention, autonomous track inspection provides a significant step forward by increasing the frequency and decreasing the cost of track inspection.

Core Technology in Autonomous Track Inspection Systems

As illustrated in Figures 1 and 3, the autonomous track inspection technology established to date generally includes three major components: onboard units, wireless communication links, and processing servers.

- *Onboard Units* – The portion of the system located on the vehicle generally consists of a series of sensors, a computing platform, and location determination technology.

  A dramatic increase in computer power and reliability, combined with a decrease in processor size, is one of the enabling factors for autonomous monitoring. Onboard equipment is becoming small enough, reliable enough, and sophisticated enough to conduct most of the operations currently performed by inspection car operators. These operations include instrumentation verification, generation of data, location marking, and exception evaluation. Although there are still operations where it is difficult to replace a human operator, particularly when something malfunctions or unexpected situations arise, these situations can be identified and the data handled appropriately in an automated fashion.

  Global Positioning System (GPS) technologies are critical to autonomous inspection in that they provide location of the detected defects in absence of an operator. Onboard GPS based location systems can have different levels of accuracy and sophistication from regular GPS receivers to Differential GPS (DGPS) to high end DGPS assisted inertial navigation systems. The use of standard GPS provides the cheapest solution, but the associated accuracy is about 40 feet (in 95% of the cases) under normal conditions with a clear view of the sky. The accuracy of GPS is significantly affected by various atmospheric conditions, as well as local terrain and can be interrupted by dense foliage, overpass bridges, tall buildings and other obstructions. At the other end of the spectrum is DGPS assisted inertial navigation systems. These systems provide uninterrupted and more accurate GPS locations even when GPS signal is temporarily interrupted or obstructed. The accuracy of these systems, depending on the type of the DGPS and inertial sensors utilized, can be as high as 1 foot. This increased accuracy comes at a cost in that it is achieved by using more expensive hardware and paying for differential correction services.

- *Processing Servers* – A key element on an autonomous inspection system is a central server to which data is transferred. This facility features data processing capabilities, a database management system, and Geographic Information Systems (GIS) applications to facilitate reporting of areas of interest.

  The nature of autonomous inspection systems greatly improves the productivity of inspection operations but can increase the volume of data to be considered. An efficient data management and reporting system is necessary to create uniform data storage, and increase the efficiency of reporting issues. GPS coordinates or other location data associated with defects are not sufficient unless there are underlying maps that show information associated with track and other rail infrastructure. This allows for conversion of location data reported by the onboard autonomous systems into standard linear railroad referencing (subdivision, MP, FT, track number). Currently, most railroads in the United States have some kind of GIS database with locations of rail infrastructure. The accuracies of these databases have a direct effect on the reliability of the location of the autonomously reported exceptions. At this time, the accuracies of GIS databases of most US carriers are not sufficient to reliably differentiate the track number using GPS data alone. However, with the advent of Positive Train Control (PTC) in the United States this is expected to change. The accuracies of GIS databases are expected to increase to a level where track number will be correctly determined.

- *Communication Links* – The manner in which data is transferred between the onboard units, the central processing servers, and the data recipients is an important feature of any autonomous inspection system. It affects the way in which measured data is uploaded to the central processing servers, and processed information is distributed to inspectors or maintenance personnel.

Wireless communication is another critical enabling technology used for retrieval of data from the onboard systems and providing remote monitoring and maintenances to the systems. Different communications approaches have been used. The aforementioned systems employed by the Class I US railroads, as well as the FRA ATGMS, uses publicly available commercial 2g and 3g data networks, while ImageMap has employed dedicated 802.11 readers installed at the end stations of the surveyed routes. In any case, the bandwidth of available wireless communications continues to increase providing opportunities to collect and upload larger data sets.

Data collected by autonomous track inspection systems can be made available to stakeholders through a variety of ways including electronic email reports, dedicated websites, and transfer to railroad data management systems.

PHASES OF AUTONOMOUS TRACK INSPECTION TECHNOLOGY INTRODUCTIONS

Similar to other revolutionary technologies, the introduction of autonomous inspection technology presents challenges that must be addressed by operators as well as regulators. These challenges include the development of safe and reliable technology, the establishment of procedures and recommended practices for system and data use, and the development of appropriate regulations. Issues associated with each of these challenges will be summarized and addressed in the following sections. Where appropriate, lessons learned at the onset of autonomous inspection will be related.

Development of Safe and Reliable Technology

From the hardware's point-of-view, autonomous inspection devices face similar challenges and requirements to other equipment installed on railroad vehicles requiring high levels of reliability including:

- Sufficient power to allow the system to function under all required conditions;
- Protection from operating environment and tampering;
- Redundant safety protection for both vehicle and personnel;
- Fire/smoke resistance requirements;
- Technical support for operation and repairs.

The onus for system safety and reliability falls on the supplier working in close coordination with the railroad. Depending on the type of the vehicle, the autonomous systems must comply with various regulations. For example, equipment installed in locomotive cabins or passenger cars must comply with a number of strict federal regulations including fire and smoke requirements. Equipment installed on the bogie or under the trains should have redundant safety mechanisms to protect them from falling on the track and causing derailment and must comply with clearance requirements; in some cases, this equipment must be subject to strict electro-magnetic interference (EMI) restrictions. In addition, equipment installed on the bogie cannot negatively affect dynamic bogie performance which may necessitate weight and size limitations. It should also be noted that some inspection systems employ lasers or high voltage. These devices must be adequately shielded in compliance with regulations so that they do not affect safety of railroad workers, passengers or people near the track.

Based on lessons learned by railroads that have implemented this type of technology, the following efforts should be considered prior to the deployment of autonomous inspection systems:

- *Maintenance Procedures*: Clear documentation of the system and its installation should be provided to, and accepted by, the appropriate maintenance departments in order for railroad personnel to develop standard procedures to address operation and maintenance of the vehicles upon which the inspection system is installed. This will provide shop personnel with instructions on how to handle maintenance work on the vehicle that may be impacted by the inspection system's presence on the vehicle. It should also have warnings to minimize the chances of damage or disconnection of the inspection system during routine maintenance activities. Maintenance procedures should also be established for the autonomous system itself to clearly establish the roles of railroad personnel and suppliers in performing maintenance and calibration activities. Maintenance procedures must include safety precautions in the event that lasers or high voltages are associated with the inspection system.

- *Operational Procedures*: Documentation and emergency instructions should be posted or accessible in all rail vehicles on which the autonomous inspection systems are installed to give the onboard crew and maintenance personnel directions in the event of issues with the system, especially in the event that the issues causes the inspection system to interfere with the mechanical or electrical operation of systems on the vehicle or the vehicle itself.

Due to the nature of its deployment, autonomous inspection technology has the additional requirement of the following features:

- Low false-alarm and missed detection rates;
- Remote diagnostic capabilities;
- Remote software updates and enhancements;
- Remote or self-recovery in the event of power interruptions;
- Reliable communications coverage and bandwidth.

The responsibility for system reliability with respect to these issues falls on the suppliers to ensure that widespread use of autonomous inspection technology is not adversely affected by reliability issues, especially those affecting confidence in data such as missed detections and/or high false alarm rates. This can be difficult when components operate in the severe and challenging railroad environment. Optical sensors pose particular challenges; with autonomous systems, regular manual cleaning of lenses and windows are not realistic. Autonomous systems employing optical sensors must be adequately protected to minimize the need for regular cleaning or have automated cleaning mechanisms. Accessibility of autonomous inspection systems can be severely limited due to revenue service operations; railroads may not delay movements or park vehicles to repair a track inspection system. To that end, systems of this nature must have means of self recovery or automated/remote recovery to be able to overcome non-critical glitches or component failures. In addition, these systems must have some level of redundancy for critical functions, high mean time between failures (MTBF), high level of maintainability and serviceability so that if the system fails, maintenance personnel can repair the system with short time frame that may be available.

Based on past experience, pilot applications of autonomous inspection technology on limited routes often serve as an opportunity to identify issues, and validate the approach and results of the system while minimizing railroad investments in time and effort required.

Establishment of Procedures and Recommended Practices for System and Data Usage

The use of autonomous inspection technology offers many benefits to the railroad industry, including high inspection frequencies, allowing for additional data availability for improved forecasting and trend analysis, and near instantaneous availability of data. This increase in data brings several challenges for the railroad, including:

- Vast amounts of information that must be considered as data will be collected at a much higher frequency as compared to traditional methods;
- The manner in which information collected with autonomous systems will be integrated and compared with data collected with the traditional, on-going inspection practices;

- Validation of events identified by the autonomous inspection system given the increased frequency in which data is reported, especially at the onset of the autonomous inspection program.

Prior to the full implementation of autonomous inspection technology, the railroad should have a clear plan on data usage. As is often done in automated inspection programs, different thresholds are used to identify issues that could grow into defects. With increased reporting frequencies, new thresholds may be warranted to monitor defect growth rates with increased sampling rates and projections of when the defects will become critical. Railroads will need to develop practices to appropriately address these changing conditions.

Follow-up activities based on reports generated by autonomous inspections represent a particular challenge to the railroad industry. The potential exists for extra costs without immediate significant benefit, especially during the introduction of the technology during the critical stage of validation, "qualification," and process modification. Based on experiences with the previously cited implementations of autonomous inspection systems, pilot applications can afford an opportunity for operators to gradually develop response plans, formulate appropriate thresholds where applicable, and grow accustomed to data flow rates.

Confidence in the data reported with this technology can often be bolstered by considering the existence of "repeated events" on consecutive surveys as a validation mechanism. Although this represents a logical approach during the initial stages of autonomous inspection deployment, this is accompanied by risk – the "knowledge" of a potential defect without immediate remedial action. This is an extremely critical issue in that it not only represents increased liability for the railroad but a regulatory issue as well. This leads directly into the third category of challenges – the development of appropriate regulations.

Development of Appropriate Regulations

Current regulations, which are largely predicated on visual inspections and infrequent but technically detailed automated inspections, may not be appropriate for the manner in which defects will be identified with autonomous track inspection systems. A railroad track inspector is obligated to correct (initiate a repair of) or protect (slow order) the track before the next train once a defect to the FRA Track Safety Standards has been determined to exist during an on-the-ground inspection. The FRA Office of Safety has generally taken the position that track defects detected during an automated track geometry survey conducted by the railroad do not necessarily require action before the next train; in a sense, the data is treated as "advisory" to the track inspector who then decides on the appropriate follow-up action. For defects that pose an imminent risk for derailment, such as wide gage, practice dictates that immediate action is taken. Because of the frequency of most automated inspections – anywhere from two or four times a year on a particular territory to monthly inspections at most – such follow-up is considered reasonable, given that the track inspector is able to observe the conditions from an inspection vehicle and decide upon appropriate follow-up actions.

FRA acknowledges that current practices and regulations may actually provide a disincentive for implementation of autonomous technology. With an increase in inspection frequency, railroads may be alerted to potential defects with great regularity, and follow-up inspections may prove costly and logistically difficult prior to the next train. Overall improvement in safety due to increased inspection frequency may justify a relief on reaction time or allowance for additional means of validation. Although difficult to commit to a plan at this stage in the development of the technology, one potential solution could involve re-evaluation of appropriate railroad response time and/or action to particular exceptions reported with an autonomous inspection system.

FRA and industry must work together to develop long-term strategic plan for implementation and usage of this technology. To that end, FRA is currently in the process of developing a "roadmap" for the implementation of autonomous inspection technologies so that it is in a position to not only be ready for the widespread use of this technology, but to promote the use of any approach that enhances safety with measurable results.

ROADMAP FOR IMPLEMENTATION OF AUTONOMOUS TECHNOLOGY

The vision of the FRA's roadmap can be summarized by the following phases of study:

- *Consideration of Risks Associated with Current Practices*: A basis for comparison of potential inspection and follow-up procedures must be established. A full evaluation of current practices based on automated inspection systems, visual inspection procedures, and autonomous track inspection systems employed to date should be conducted to determine risks associated with existing approaches. Results should lead to an assessment of top overall cost and risks associated with current inspection processes. Considerations should include:
    - Defect types, growth rates, and sizes pertaining to detection and safety criticality;
    - Probability of detection;
    - Inspection frequency;
    - Time associated with preventive action as well as corrective action;
    - Track time and manpower required for follow-up inspection.

- *Review Previous Approaches:* In order to avoid issues encountered during previous implementations of both automated and autonomous technology, a review of approaches applied in the United States and abroad should be conducted. The technologies considered should include, but not be limited to, those discussed in this paper (e.g. Amtrak's ARMS, FRA's ATGMS) as well as examples of other autonomous systems employed in the railroad industry that focus on vehicles as opposed to track, such as wheel impact detectors or hot-box detectors.

- *Determination of Appropriate Trial Processes:* Results from the aforementioned assessments should be considered to determine appropriate response time to events, changes in frequency of current inspections, and proper utilization of inspection data to guide and prioritize visual inspections.

- *Implementation of New Inspection Processes in Pilot Project(s)*: Trial processes, especially those with implication(s) to the Track Safety Standards, should be implemented within pilot studies that are established with host railroad(s) in cooperation with FRA. Projects of this nature are already in process as well as in the planning stages. The FRA's ATGMS has been in operation on Amtrak's Auto Train route in cooperation with both Amtrak and CSX Transportation. Future pilot programs are in the planning stages. Important considerations in a pilot study could include:
  - Review and analysis of results such as costs, service failures, slow orders, derailments (if any) and worst track conditions found during the trial;
  - Anecdotal evidence of problems which were allowed to continue because autonomous inspections were halted because too many defects had been found;
  - Estimates on the overall productivity of inspection processes.

As FRA Office of Research and Development formulates and refines this roadmap, it continues to reach out to industry and labor to assess and refine its approach.

CLOSING THOUGHTS

The development of autonomous inspection technologies is critical to improving efficiency and reducing the number of track caused derailments throughout the railroad industry. Industry and regulators need to take active steps to encourage the progress of these critical initiatives and acceptance of this technology. The ideas expressed in this paper are intended to provide guidance to railroads beginning to evaluate and employ this technology, and provide insight into the intentions of the FRA to foster adoption of this technology.

ACKNOWLEDGEMENTS

The authors would like to thank those in the industry who have adopted autonomous technology to date, as well as those that have supported the recent development of autonomous track geometry inspection. In particular, the contributions of Paul Steets and Michael Trosino of Amtrak, and Mr. Ronald Bright of CSX Transportation in the efforts to develop the FRA's ATGMS are greatly appreciated. The authors would also like to acknowledge the contributions to this paper of Mr. Kevin Kesler of the FRA Office of Research and Development.

REFERENCES

1. Department of Transportation, Federal Railroad Administration, "Track Safety Standards," Final Rule, 49 Code of Federal Regulations Part 213, June 22, 1998.

LIST OF FIGURES

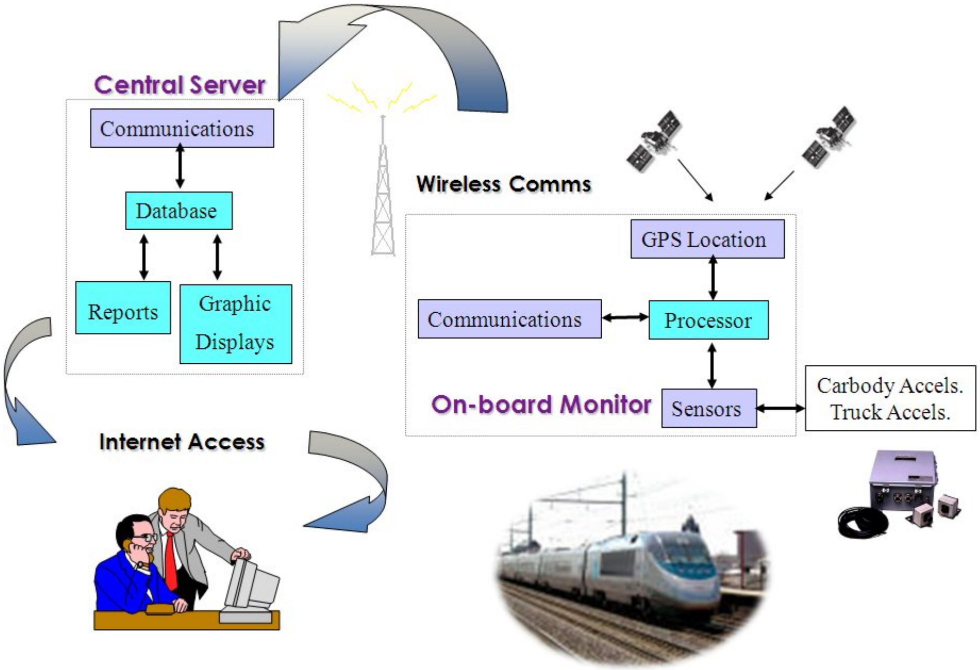


Figure 1. Concept Behind Amtrak's ARMS

On-Board ARMS Junction Box/Processor

Roof-Mounted GPS Antenna

Truck-Mounted Sensor

Figure 2. Vehicle-Mounted Components of Amtrak's ARMS

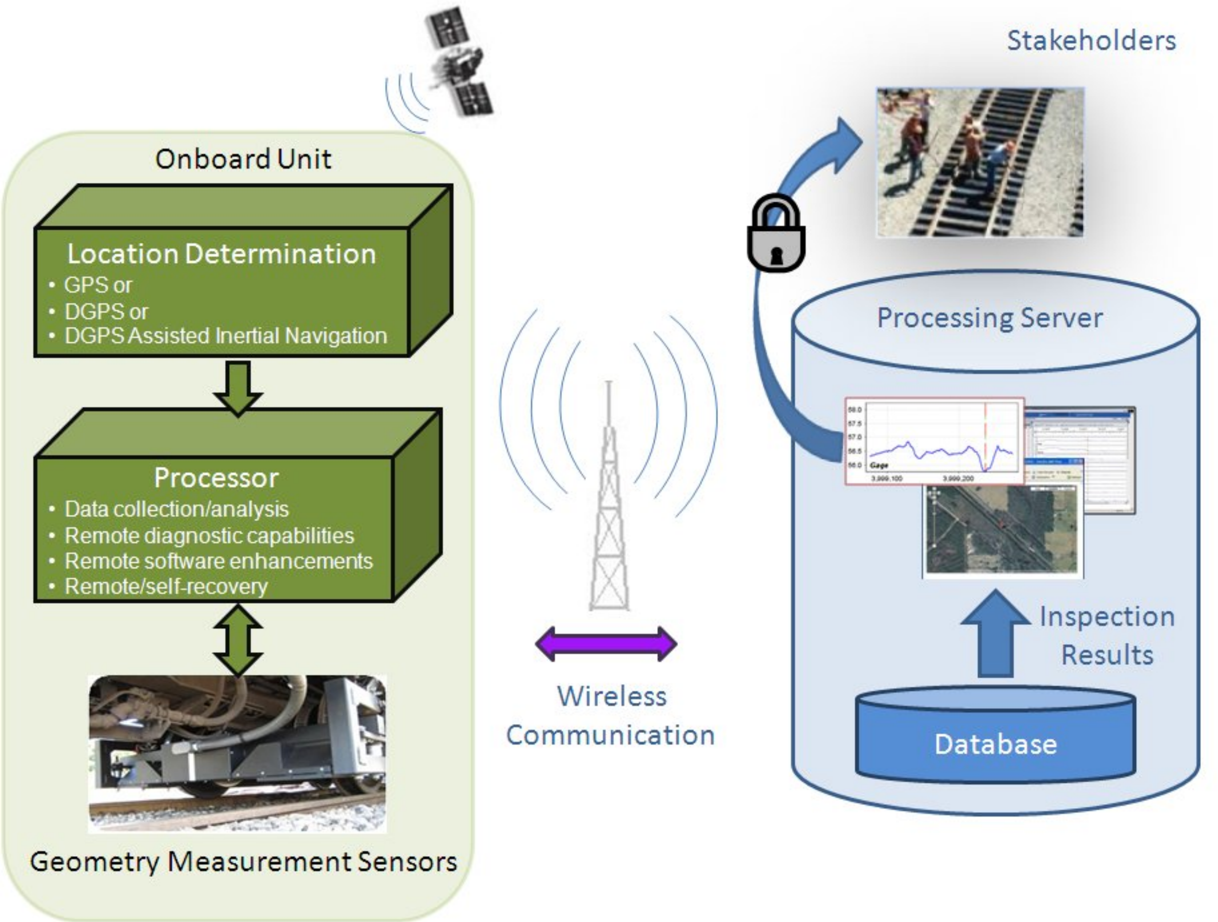


Figure 3. FRA's ATGMS Installation and Web-Based Reporting Application

Exhibit 6

Regulatory Reform

Washington, DC

APRIL 24, 2018

Agenda Outline

- Opening Comments
- Current Regulatory Reform Initiatives
  - Heavy point frogs, ¾ concrete ties, flange bearing frogs, continuous rail testing, fouled ballast waiver
- Performance Based Regulations and proposed BNSF pilot
  - Suspend inspection requirements in 213.233 Subpart F
  - Identification/Commitment to a pilot area
  - Establish "roadbed" framework for reform opportunities that can be transitioned to the field for joint implementation, execution, and measurement/evaluation
  - Establish regular communication process for pilot progress updates, new initiatives, and waiver progression as appropriate
- Next Steps

BNSF-FRA Regulatory Partnership Opportunities

Engineering – Automated Inspections

- ***Problem Defined:***
- Current requirements create unnecessary exposure to MW employees performing track inspections that can be done more effectively via existing technology
- Regulations quantify defects and prescribe remedial action vs leveraging technology to advance preventive maintenance processes

- ***Vision / Idea Developed:***
- Dedicated inspection platform and subdivision segment(s) to demonstrate autonomous track inspection capabilities.
- Scalable to other segments of the railroad
- Suspend inspection requirements in 213.233 Subpart F
- Establish standards to allow layering of other performance based activities (e.g. rail inspection, safety, cwr & ballast maintenance, etc.)

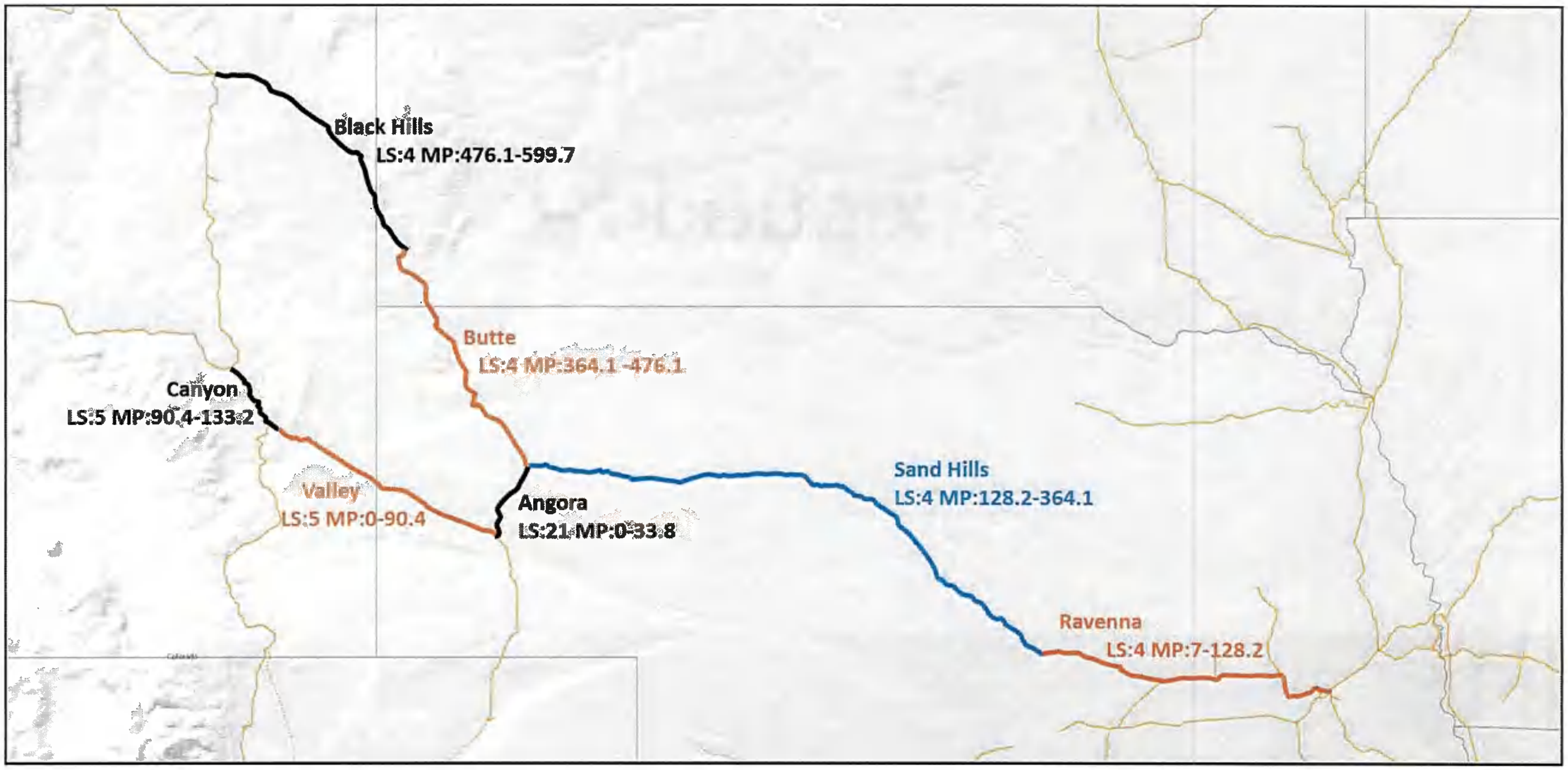
- **Measurement & Benefits:**
- Reduced safety exposures associated with on track hirail and walking inspections
- Higher quality inspection and defect detection, reducing service interruptions while supporting predictive vs reactive maintenance.
- Waiver facilitates development of next-level on board testing technology.

- **Plan / Timeline / Milestones:**
- 3-6 month test phase

Pilot Summary

- Leverage track inspection technology to enhance infrastructure integrity, mitigate inspector exposure, and improve freight capacity
- Select pilot territory to transition to a performance-based regulatory environment
- Partner with FRA to develop/evaluate inspection methods, frequencies, and track health metrics
- Establish “roadbed” at the senior level, allow the joint field teams to execute the development process
- Establish communication schedule/structure to monitor/discuss results, and adjust pilot processes as necessary, while providing a regular forum to present additional technology opportunities moving forward
- Progress pilot to waiver when appropriate, rolling out enhanced processes to other BNSF territories, maintaining “roadbed” and communication structure

Exhibit A pilot proposal map



880 ROUTE MILE.

1700 TOTAL TRACK MILE

Appendix

Future of Track Inspection

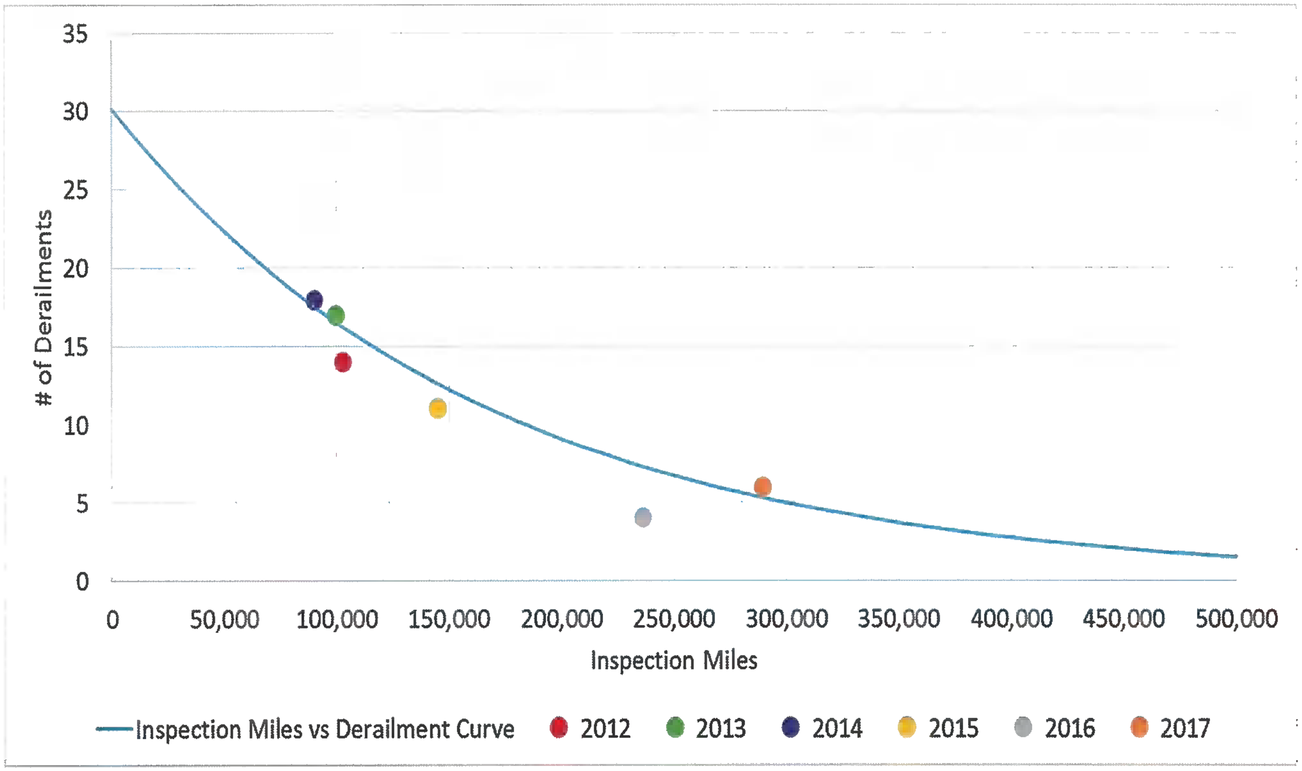
Future of Track Inspection

“A periodic, performance-based use of advanced inspection methods can improve the identification of existing track conditions and their deficiencies. The data achieved by the use of these technologies will enable the track inspector to more effectively verify and focus on the identified track anomalies; monitor those track segments bordering on potential defects; perform routine right-of-way property inspection for unsafe conditions; perform emergency and special inspections; perform emergency repairs and/or take appropriate remedial action in a timely manner; and, monitor the results of track work performed or in progress.

Railroads with the vision to invest in new technologies to better inspect and detect defects in the track structure should be provided the opportunity to modify the current visual inspection requirements.”

NTSB Safety Recommendation 9/24/97

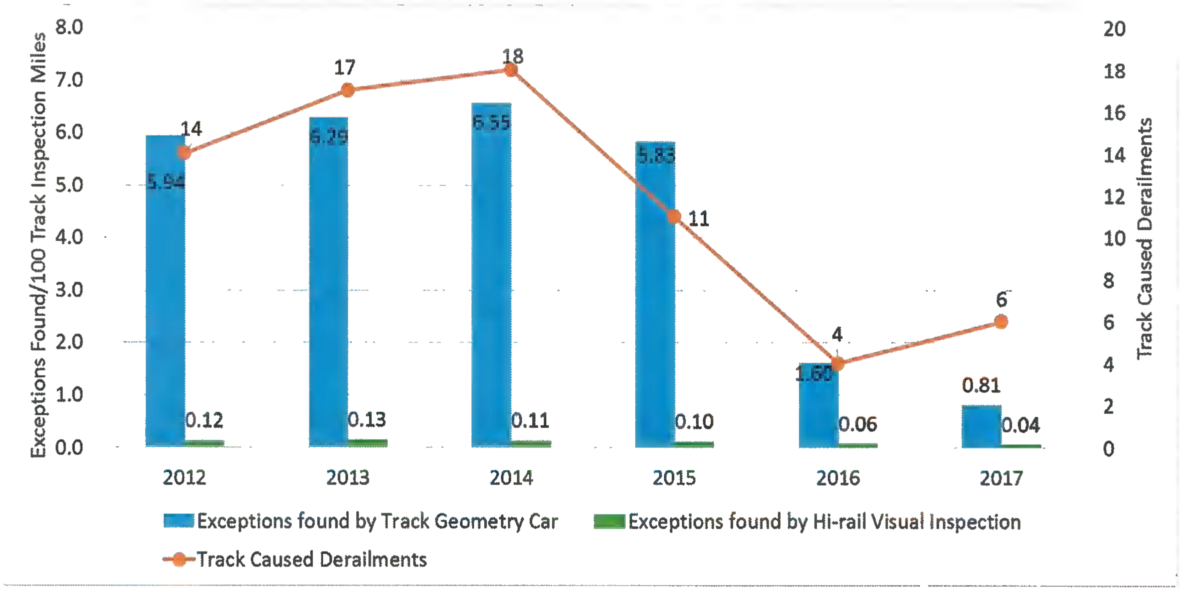
Effective Inspections Utilizing Data



Track Geometry Car Inspection Miles & Number of Derailments

- Mainline Track Caused Derailments Only T001-T199
- Gage, Alignment & Surface Exceptions

Correlation Between Geo Inspection Miles & Derailments

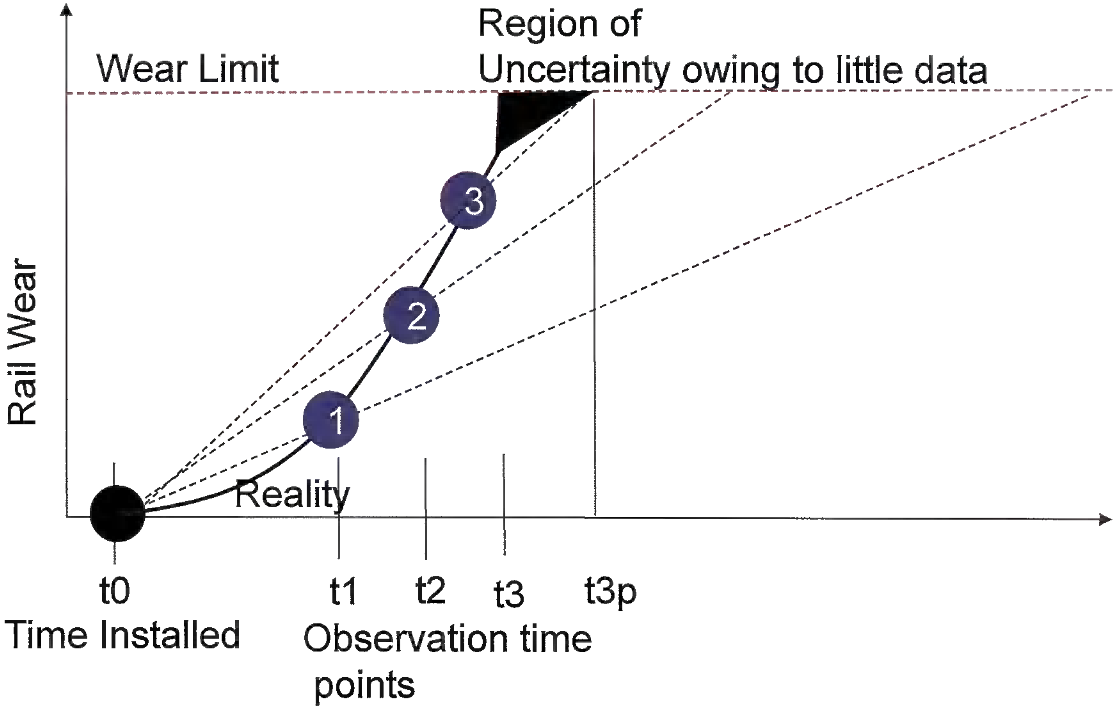


- Track Geometry Car Inspection Miles & Number of Derailments
  - Mainline Track Caused Derailments Only
    - T001-T199
    - T109 not included
  - All Railbound TG Car Inspections
  - Gage, Alignment & Surface Defects
- Increased inspections have allowed Capital Planning to be pointed where needed

Data Based Inspection Tools - Curve Model

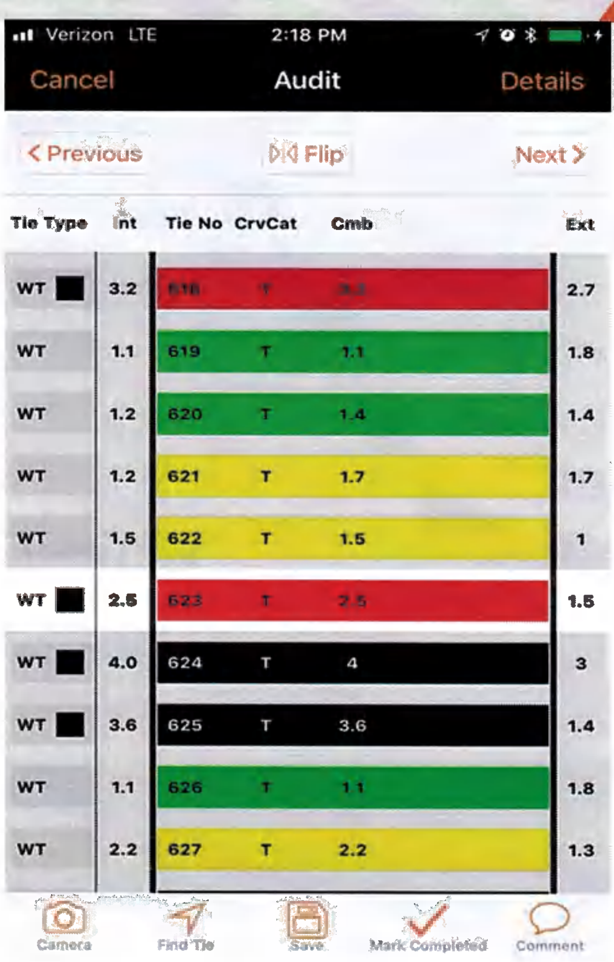
Predicts rail wear using regression modeling:

- Rail wear data from geometry car
- MGT
- Degree of Curvature
- Model is not linear, accommodates acceleration of wear

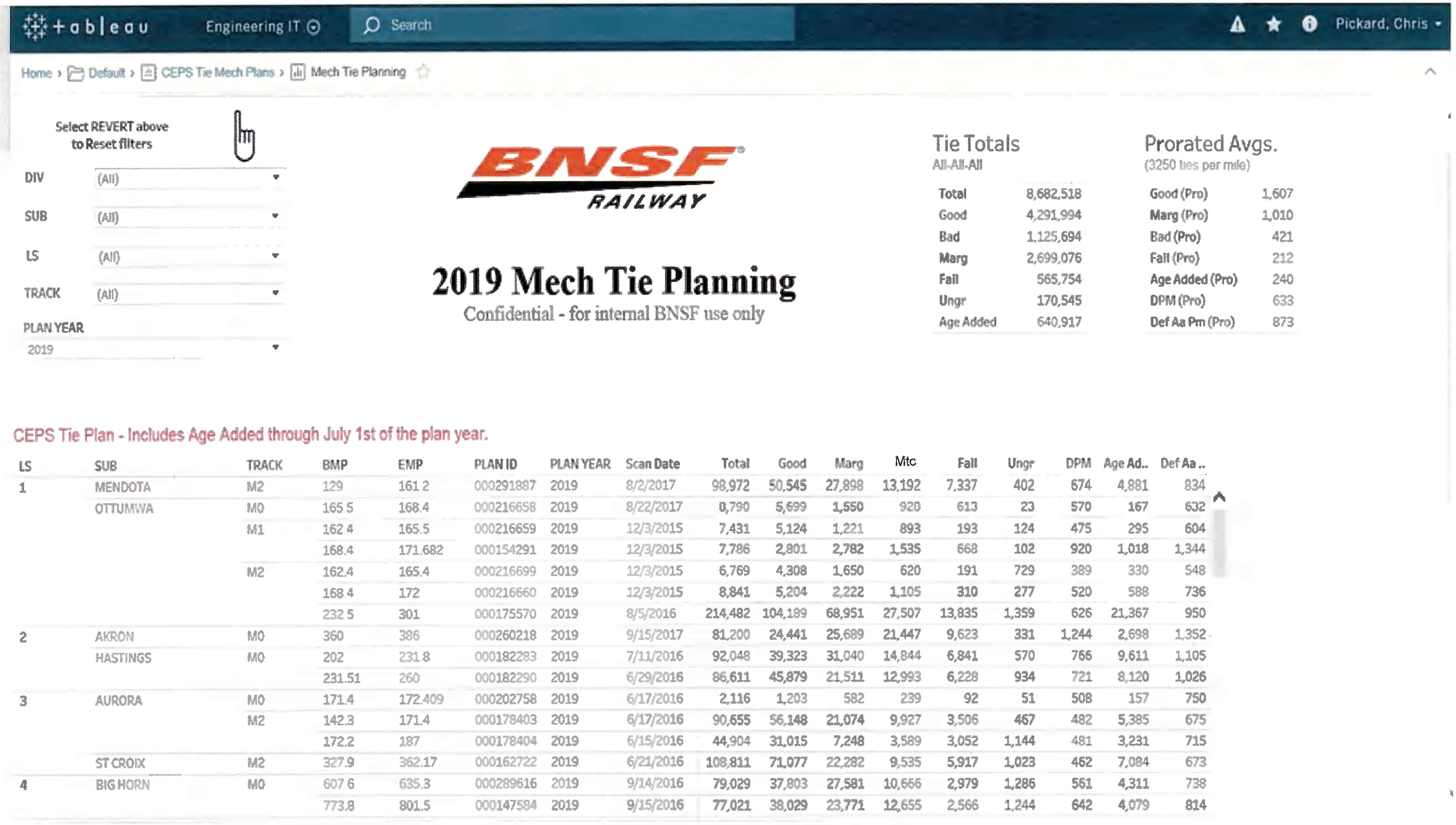


Tie Marking/Grading IPhone App

- Tie Type
- Int – Internal score
- Tie No - tie number in that mile
- CrvCat - T=Tangent, L=Light, M=Moderate, S=Severe
- Cmb - combined internal and external scores
- Ext - external score
- App allows for comments/pictures on any tie to include in your inspection



Tie Type	Int	Tie No	CrvCat	Cmb	Ext
WT ■	3.2	618	T	3.2	2.7
WT	1.1	619	T	1.1	1.8
WT	1.2	620	T	1.4	1.4
WT	1.2	621	T	1.7	1.7
WT	1.5	622	T	1.5	1
WT ■	2.5	623	T	2.5	1.5
WT ■	4.0	624	T	4	3
WT ■	3.6	625	T	3.6	1.4
WT	1.1	626	T	1.1	1.8
WT	2.2	627	T	2.2	1.3



Select REVERT above
to Reset filters

DIV (All)
SUB (All)
LS (All)
TRACK (All)
PLAN YEAR 2019

BNSF RAILWAY

2019 Mech Tie Planning

Confidential - for internal BNSF use only

Tie Totals

All-All-All

Total	8,682,518
Good	4,291,994
Bad	1,125,694
Marg	2,699,076
Fail	565,754
Ungr	170,545
Age Added	640,917

Prorated Avgs.

(3250 ties per mile)

Good (Pro)	1,607
Marg (Pro)	1,010
Bad (Pro)	421
Fail (Pro)	212
Age Added (Pro)	240
DPM (Pro)	633
Def Aa Pm (Pro)	873

CEPS Tie Plan - Includes Age Added through July 1st of the plan year.

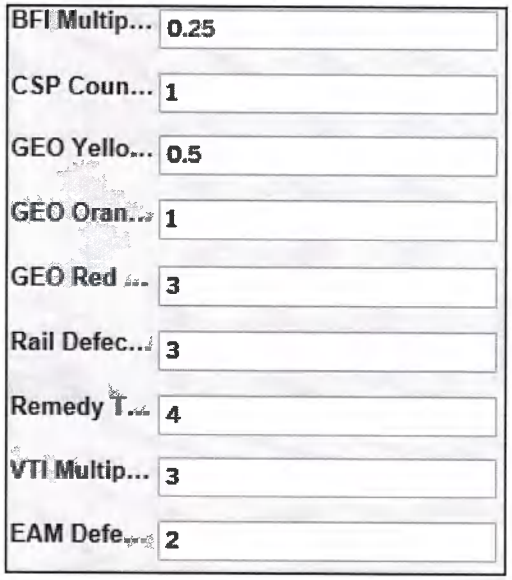
LS	SUB	TRACK	BMP	EMP	PLAN ID	PLAN YEAR	Scan Date	Total	Good	Marg	Mtc	Fail	Ungr	DPM	Age Ad..	Def Aa ..
1	MENDOTA	M2	129	161 2	000291887	2019	8/2/2017	98,972	50,545	27,898	13,192	7,337	402	674	4,881	834
	OTTUMWA	M0	165 5	168.4	000216658	2019	8/22/2017	8,790	5,699	1,550	920	613	23	570	167	632
		M1	162 4	165.5	000216659	2019	12/3/2015	7,431	5,124	1,221	893	193	124	475	295	604
			168.4	171.682	000154291	2019	12/3/2015	7,786	2,801	2,782	1,535	668	102	920	1,018	1,344
		M2	162.4	165.4	000216699	2019	12/3/2015	6,769	4,308	1,650	620	191	729	389	330	548
			168 4	172	000216660	2019	12/3/2015	8,841	5,204	2,222	1,105	310	277	520	588	736
			232 5	301	000175570	2019	8/5/2016	214,482	104,189	68,951	27,507	13,835	1,359	626	21,367	950
2	AKRON	M0	360	386	000260218	2019	9/15/2017	81,200	24,441	25,689	21,447	9,623	331	1,244	2,698	1,352
	HASTINGS	M0	202	231 8	000182283	2019	7/11/2016	92,048	39,323	31,040	14,844	6,841	570	766	9,611	1,105
			231.51	260	000182290	2019	6/29/2016	86,611	45,879	21,511	12,993	6,228	934	721	8,120	1,026
3	AURORA	M0	171.4	172.409	000202758	2019	6/17/2016	2,116	1,203	582	239	92	51	508	157	750
		M2	142.3	171.4	000178403	2019	6/17/2016	90,655	56,148	21,074	9,927	3,506	467	482	5,385	675
			172.2	187	000178404	2019	6/15/2016	44,904	31,015	7,248	3,589	3,052	1,144	481	3,231	715
	ST CROIX	M2	327.9	362.17	000162722	2019	6/21/2016	108,811	71,077	22,282	9,535	5,917	1,023	462	7,084	673
4	BIG HORN	M0	607 6	635.3	000289616	2019	9/14/2016	79,029	37,803	27,581	10,666	2,979	1,286	561	4,311	738
			773.8	801.5	000147584	2019	9/15/2016	77,021	38,029	23,771	12,655	2,566	1,244	642	4,079	814

Turnout Reliability

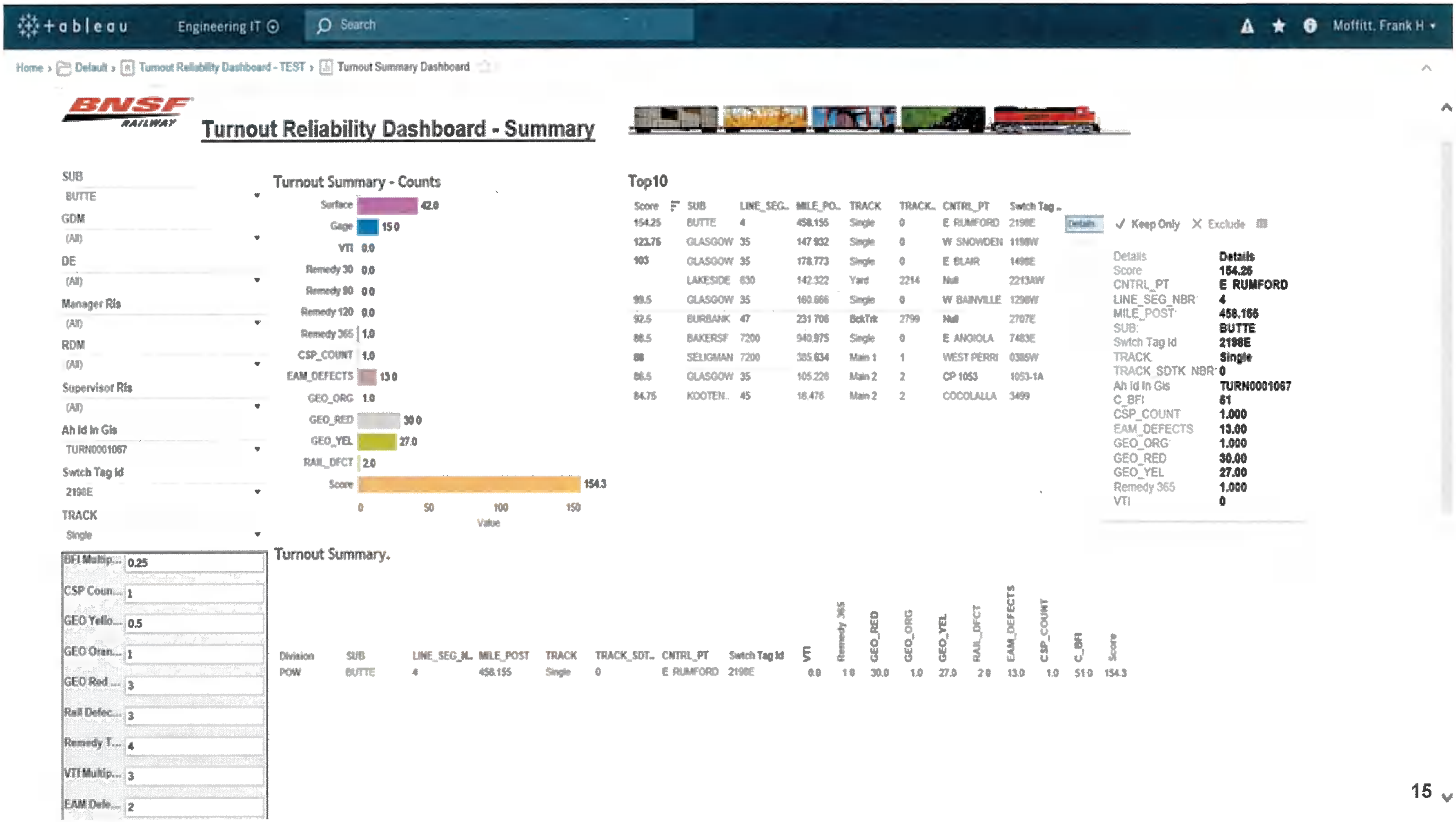
Model aggregates all pertinent condition data and includes;

- Inventory
- Ballast Fouling Index
- Comp Surf Plan
- Geo Tags
- Rail Defects
- Remedy Trouble Tickets
- VTI's
- EAM Reported Defects TRACK INSP
- Maintenance Activities

Metric Weighting



BFI Multip...	0.25
CSP Coun...	1
GEO Yello...	0.5
GEO Oran...	1
GEO Red ...	3
Rail Defec...	3
Remedy T...	4
VTI Multip...	3
EAM Defe...	2



Turnout Reliability Dashboard - Summary

SUB	BUTTE
GDM	(All)
DE	(All)
Manager Rls	(All)
RDM	(All)
Supervisor Rls	(All)
Ah Id In Gis	TURN0001067
Swtch Tag Id	2198E
TRACK	Single

BFI Multip...	0.25
CSP Coun...	1
GEO Yello...	0.5
GEO Oran...	1
GEO Red ...	3
Rail Defec...	3
Remedy T...	4
VTI Multip...	3
EAM Dele...	2

Turnout Summary - Counts

Top10

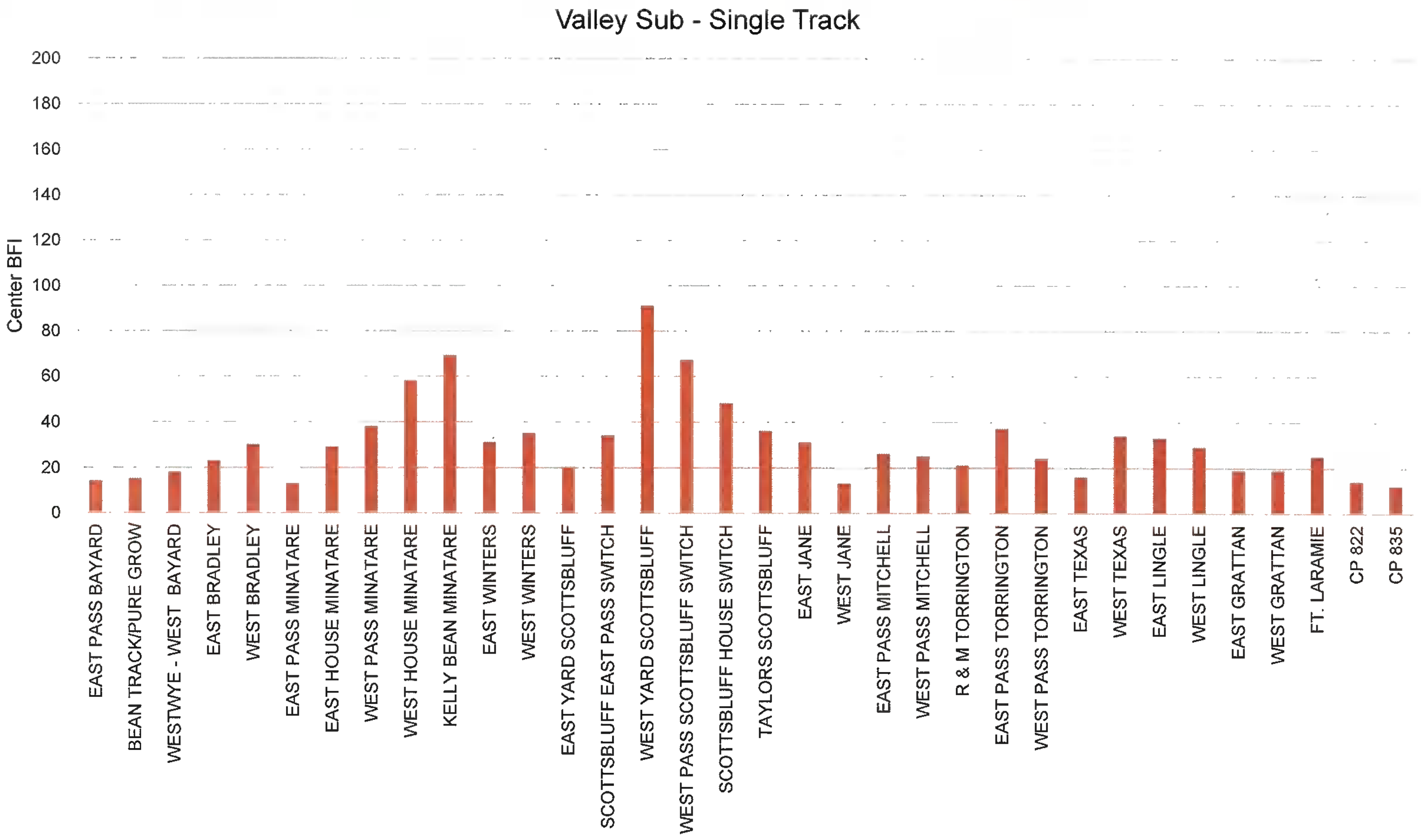
Score	SUB	LINE_SEG..	MILE_PO..	TRACK	TRACK..	CNTRL_PT	Swtch Tag ..
154.25	BUTTE	4	458.155	Single	0	E RUMFORD	2198E
123.75	GLASGOW	35	147.932	Single	0	W SNOWDEN	1198W
103	GLASGOW	35	178.773	Single	0	E BLAIR	1498E
	LAKESIDE	630	142.322	Yard	2214	Null	2213AW
99.5	GLASGOW	35	160.866	Single	0	W BAINVILLE	1298W
92.5	BURBANK	47	231.706	BckTrk	2799	Null	2707E
88.5	BAKERSF	7200	940.975	Single	0	E ANGIOLA	7483E
88	SELIGMAN	7200	385.634	Main 1	1	WEST PERRI	0385W
86.5	GLASGOW	35	105.228	Main 2	2	CP 1053	1053-1A
84.75	KOOTEN..	45	18.476	Main 2	2	COCOLALLA	3499

Details	Details
Score	154.25
CNTRL_PT	E RUMFORD
LINE_SEG_NBR	4
MILE_POST	458.155
SUB:	BUTTE
Swtch Tag Id	2198E
TRACK	Single
TRACK_SDTK_NBR	0
Ah Id In Gis	TURN0001067
C_BFI	51
CSP_COUNT	1.000
EAM_DEFECTS	13.00
GEO_ORG	1.000
GEO_RED	30.00
GEO_YEL	27.00
Remedy 365	1.000
VTI	0

Turnout Summary.

Division	SUB	LINE_SEG_N..	MILE_POST	TRACK	TRACK_SDT..	CNTRL_PT	Swtch Tag Id	VTI	Remedy 365	GEO_RED	GEO_ORG	GEO_YEL	RAIL_DFCT	EAM_DEFECTS	CSP_COUNT	C_BFI	Score
POW	BUTTE	4	458.155	Single	0	E RUMFORD	2198E	0.0	1.0	30.0	1.0	27.0	2.0	13.0	1.0	51.0	154.3

Center BFI – Valley Sub



Orange Tags – Predictive Analytics

Orange Tags are new exceptions developed to focus inspection and help prioritize surfacing behind a Geometry Car. Orange Tags represent track conditions that have higher priority than Yellow Tags but do not reach Red Tag limits.

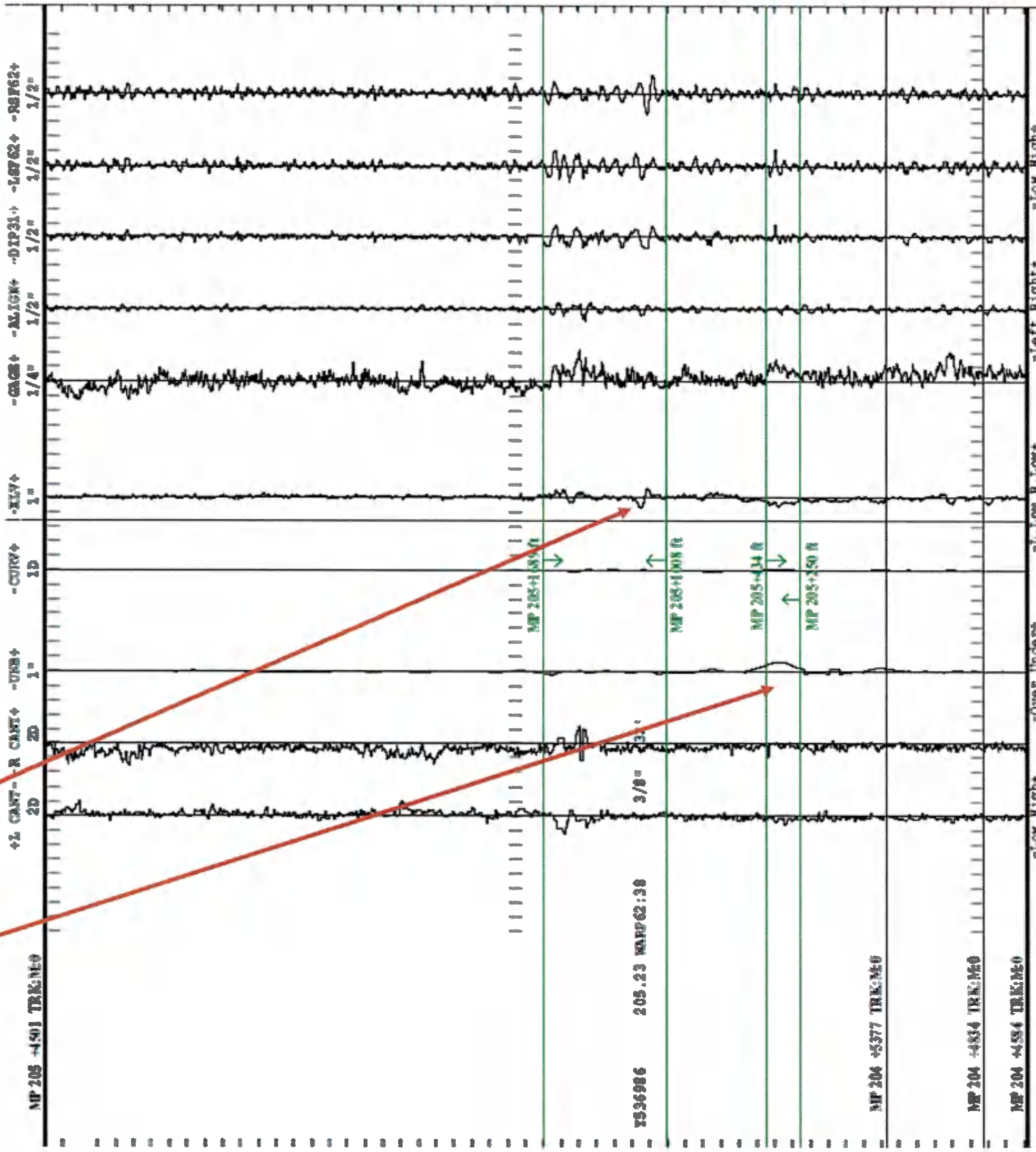
How are Orange Tags determined?

Predictive analytics: surface Yellow Tags are evaluated based on an algorithm that predicts whether or not the tag will turn Red in 30 days. These include cross level, surface and alignment with warp soon to come.

By established exception limits: Defined Orange Tag limits have been established for Gage, Cant and Rail Wear exceptions. Gage and Cant are set at half the difference between Red and Yellow Tag limits.

Orange Tags must be inspected within three days following a Geo Car.

Comprehensive Surface Plan



CSP was developed thru machine learning using foot by foot Geo data with additional rule sets.

Rule sets include;
crosslevel 5/8" > in Class 4 track, ½" > in Class 5. Curves over elevated 1">, surface1" >, alignment ½" >

It is post processed and available by 0900 the next day.

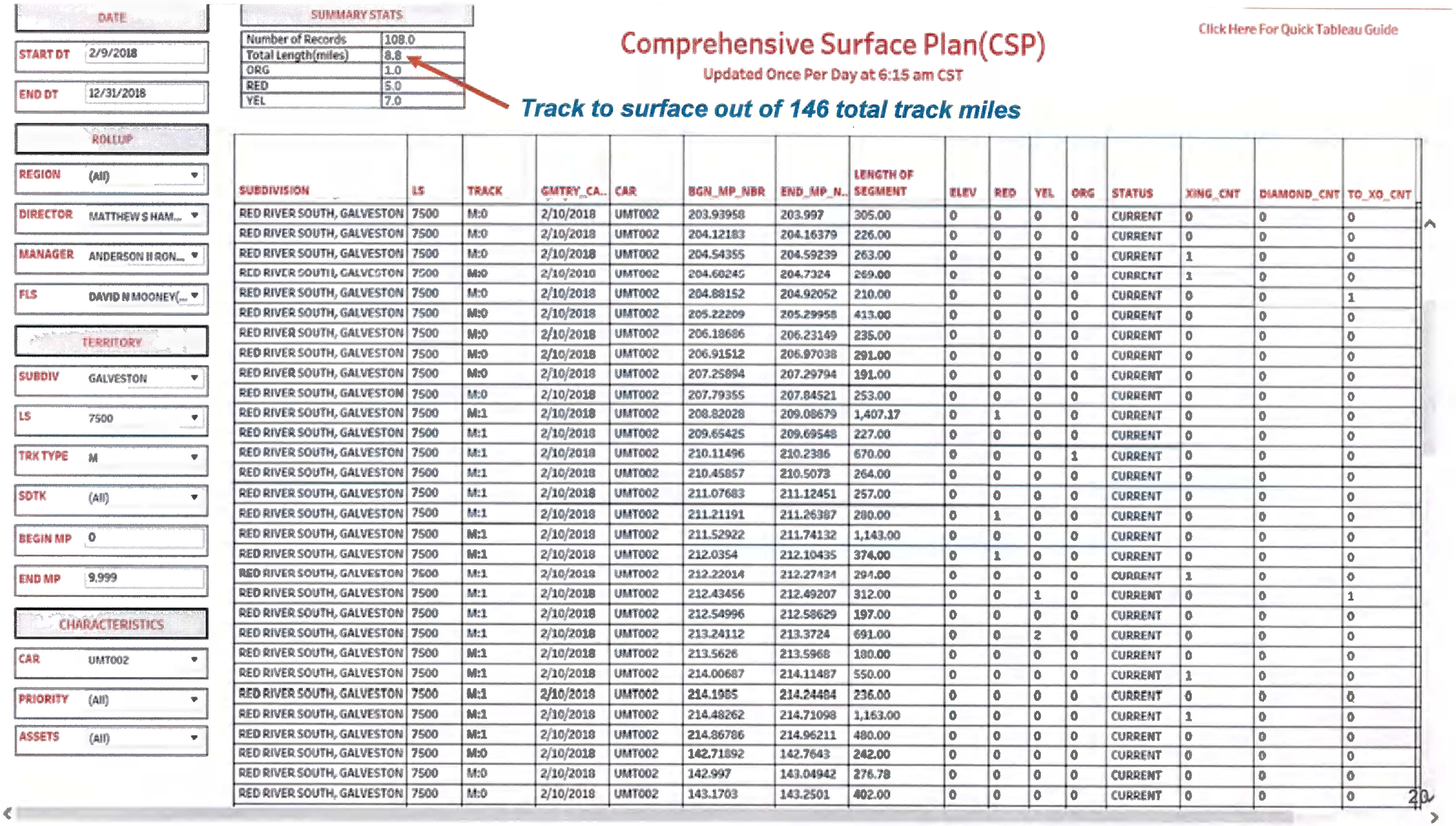
- Yellow Tag Exception of Warp for 32'
Total CSP at this location is 716'

An Additional CSP is identified of 193' of track without any yellow, orange, or red tag exceptions.

Comprehensive Surfacing Plan Prioritization Model

Prioritization Mode	Window Requirements	Territory Recommendations	Type of Territory	Training	
Mode 1 Firefighter	Leverage any window	Fallbridge	Single Track/CTC	Wk Feb 26th	
		Galveston	Single Track/CTC	Wk Feb 19th	
Mode 2 Reactive	Leverage large windows when available– Prod gang, surfacing, welding etc.	Marceline	Double Track/CTC	Late Feb	
		Lampasas	Single Track/CTC	Wk March 1st	
Mode 3 Proactive	Surfacing is the anchor window	Dickinson	Single Track	Wk March 19th	
Mode 4 Hybrid Pro/F.F.	Surfacing is anchor/leverage any window* *Two tampers, one in Mode 1, 1 in mode 3	Hannibal	Single Track	Early March	

Priority Levels	
Mode 1	All CSP segments with red and orange tags
Mode 2	All CSP segments with red and orange tags plus yellow tags, curves with reverse crosslevel and curves over elevated by ≥ 1.5"
Mode 3	All CSP segments, includes all above plus curves over elevated by ≥ 1"
All Modes	*Influence prioritization by including or excluding assets (turnouts and road crossings), for example, Proactive minus could be all CSP segments excluding turnouts and crossings w/o a geo tag.*



Comprehensive Surface Plan(CSP)

Updated Once Per Day at 6:15 am CST

Click Here For Quick Tableau Guide

Track to surface out of 146 total track miles

DATE

START DT 2/9/2018

END DT 12/31/2018

ROLLUP

REGION (All)

DIRECTOR MATTHEW S HAM...

MANAGER ANDERSON II RON...

FLS DAVID N MOONEY(...

TERRITORY

SUBDIV GALVESTON

LS 7500

TRK TYPE M

SDTK (All)

BEGIN MP 0

END MP 9,999

CHARACTERISTICS

CAR UMT002

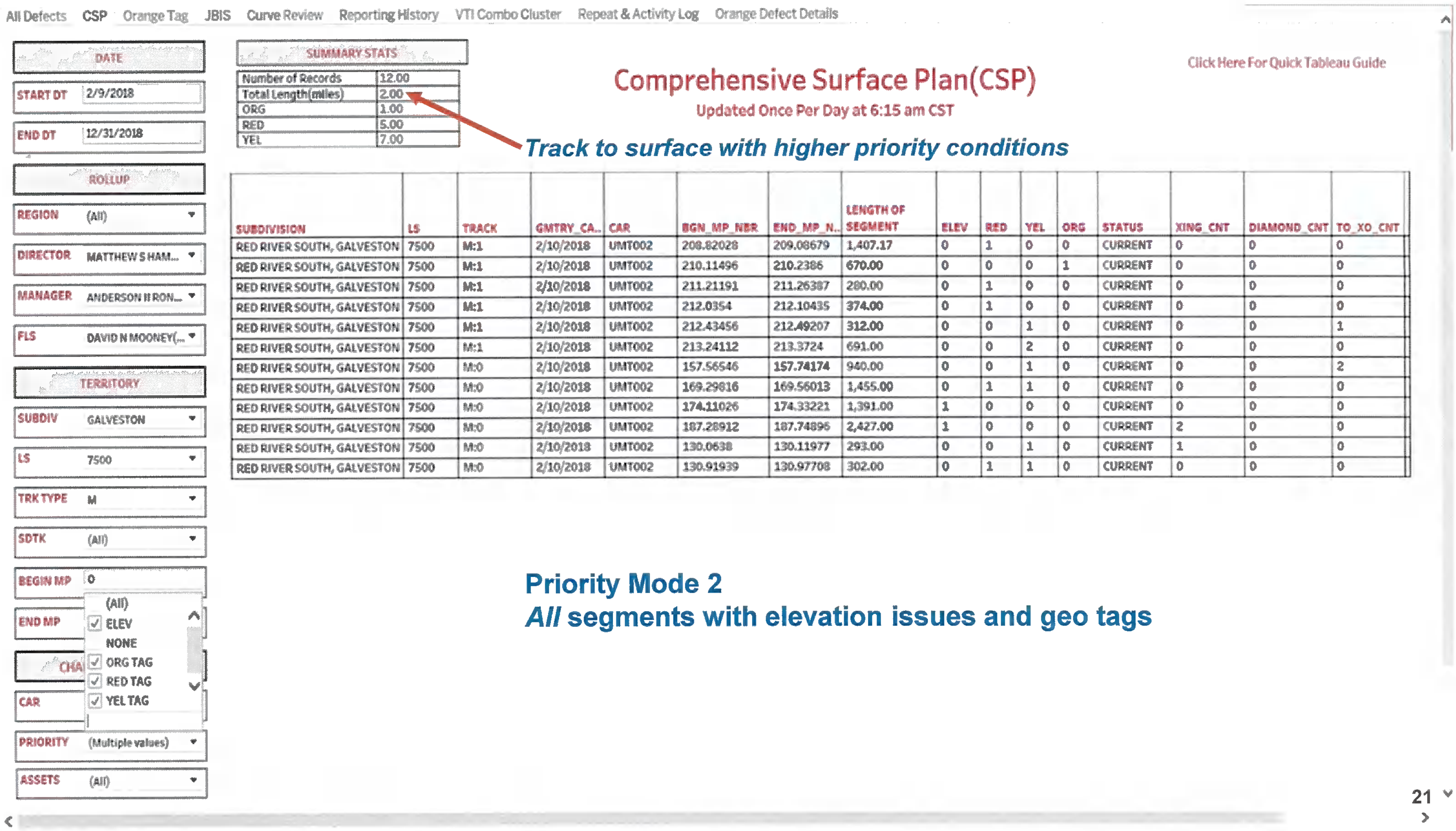
PRIORITY (All)

ASSETS (All)

SUMMARY STATS

Number of Records	108.0
Total Length(miles)	8.8
ORG	1.0
RED	5.0
YEL	7.0

SUBDIVISION	LS	TRACK	GMTRY_CA..	CAR	BGN_MP_NBR	END_MP_N..	LENGTH OF SEGMENT	ELEV	RED	YEL	ORG	STATUS	XING_CNT	DIAMOND_CNT	TO_XO_CNT
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	203.93958	203.997	305.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.12183	204.16379	226.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.54355	204.59239	263.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2010	UMT002	204.60245	204.7324	269.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.88152	204.92052	210.00	0	0	0	0	CURRENT	0	0	1
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	205.22209	205.29958	413.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	206.18686	206.23149	235.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	206.91512	206.97038	291.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	207.25894	207.29794	191.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	207.79355	207.84521	253.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	208.82028	209.08679	1,407.17	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	209.65425	209.69548	227.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	210.11496	210.2386	670.00	0	0	0	1	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	210.45857	210.5073	264.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.07683	211.12451	257.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.21191	211.26387	280.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.52922	211.74132	1,143.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.0354	212.10435	374.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7600	M:1	2/10/2018	UMT002	212.22014	212.27434	294.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.43456	212.49207	312.00	0	0	1	0	CURRENT	0	0	1
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.54996	212.58629	197.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	213.24112	213.3724	691.00	0	0	2	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	213.5626	213.5968	180.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.00687	214.11487	550.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.1985	214.24484	236.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.48262	214.71098	1,163.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.86786	214.96211	480.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	142.71892	142.7643	242.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	142.997	143.04942	276.78	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	143.1703	143.2501	402.00	0	0	0	0	CURRENT	0	0	0



Comprehensive Surface Plan(CSP)

Updated Once Per Day at 6:15 am CST

DATE

START DT 2/9/2018

END DT 12/31/2018

ROLLUP

REGION (All)

DIRECTOR MATTHEW S HAM...

MANAGER ANDERSON II RON...

FLS DAVID N MOONEY(...

TERRITORY

SUBDIV GALVESTON

LS 7500

TRK TYPE M

SDTK (All)

BEGIN MP 0

END MP

(All)
☑ ELEV
NONE
☑ ORG TAG
☑ RED TAG
☑ YEL TAG

CHA

CAR

PRIORITY (Multiple values)

ASSETS (All)

SUMMARY STATS

Number of Records	12.00
Total Length(miles)	2.00
ORG	1.00
RED	5.00
YEL	7.00

Track to surface with higher priority conditions

SUBDIVISION	LS	TRACK	GMTRY_CA..	CAR	BGN_MP_NBR	END_MP_N..	LENGTH OF SEGMENT	ELEV	RED	YEL	ORG	STATUS	XING_CNT	DIAMOND_CNT	TO_XO_CNT
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	208.82028	209.08679	1,407.17	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	210.11496	210.2386	670.00	0	0	0	1	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.21191	211.26387	280.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.0354	212.10435	374.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.43456	212.49207	312.00	0	0	1	0	CURRENT	0	0	1
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	213.24112	213.3724	691.00	0	0	2	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	157.56546	157.74174	940.00	0	0	1	0	CURRENT	0	0	2
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	169.29816	169.56013	1,455.00	0	1	1	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	174.11026	174.33221	1,391.00	1	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	187.28912	187.74896	2,427.00	1	0	0	0	CURRENT	2	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	130.0638	130.11977	293.00	0	0	1	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	130.91939	130.97708	302.00	0	1	1	0	CURRENT	0	0	0

Priority Mode 2

***All* segments with elevation issues and geo tags**

BNSF®
RAILWAY

Exhibit 7

BEFORE THE FEDERAL RAILROAD ADMINISTRATION

PETITION FOR A TEMPORARY SUSPENSION OF 49 C.F.R. § 213.233 TO ALLOW FOR THE TESTING OF AUTOMATED TRACK INSPECTION METHODOLOGIES

SUBMITTED BY
BNSF Railway

Pursuant to 49 C. F.R. § 211.51, BNSF Railway (BNSF), submits the following petition for a temporary suspension of 49 C.F.R. § 213.233 to allow it to test automated track inspection methodologies that will leverage technologies to enhance infrastructure integrity, reduce inspector exposure associated with track hi-rail and walking inspections, improve quality and defect detection, and enhance freight capacity. Section 211.51 allows BNSF to petition FRA for a temporary suspension of these requirements to permit a pilot program conducted on a segment of the BNSF system to demonstrate the use of such technologies.

Performing manual visual hi-rail track inspection creates unnecessary exposure to maintenance-of-way employees, given the ability to use technology to accomplish the same task. Periodic, performance-based use of one or more of these available advanced inspection methods provides a record of continuous measurable data for the actual track conditions, and offers a more consistent and comprehensive evaluation of track infrastructure integrity. Measuring the track, under load and at track speed, and creating an accurate record of each inspection, also facilitates the use of data analytics to create a predictive vs reactive maintenance environment. It will improve the identification of existing track conditions and their deficiencies, enabling track inspectors and maintenance of way employees to more effectively verify and focus on the identified track anomalies, address any defects found by the automated inspection, proactively schedule preventative maintenance activities before locations progress to defects, and make more efficient use of their inspection resources.

BNSF proposes to establish an automated track inspection pilot program with the following parameters:

1. BNSF's initial pilot location will involve portions of main track and sidings on the Ravenna, Sand Hills, Butte, Black Hills, Canyon, Valley and Angora subdivisions on the Powder River Division. See Exhibit A for map of the proposed area.
2. BNSF intends to utilize a phased implementation approach, increasing automated testing frequency while evaluating appropriate supplemental manual inspection parameters.
3. Identification and evaluation of performance-based track health metrics will be utilized to determine effectiveness of the automated inspection program.
4. Appropriate adjustment of the pilot processes will be made, as necessary, based on review of the results obtained during the test pilot and discussions with FRA leadership concerning other available technologies.

The FRA has recognized the benefits of automated track inspection technology in 1975 when it waived requirements of § 213.233 and allowed Long Island Railroad to utilize track geometry cars (TGCs) to supplement manual visual inspections.[1] Over the course of

---

[1] This waiver remains in place today.

the last four decades, automated track inspection technologies have continued to advance, and new technologies have been developed that surpass what can be detected with manual visual hi-rail inspection processes. For example, laser vision systems with backscatter x-ray technology drives tie replacement, ground penetrating radar drives ballast renewal programs, "run-over-run" big data analytics drives track surfacing programs, Vehicle track interaction (VTI)-equipped locomotives measure and monitor track/car dynamics, and automated optical systems use machine learning to detect potential defects. Advancements in high precision GPS mapping, data storage and processing speeds, and overall network connectivity allow TGCs to run in unmanned mode dramatically increasing productivity and the volume of track health data produced. BNSF data scientists use the track health data working with our field subject matter experts to develop algorithms and predictive models which then drive maintenance activities.

This test pilot is consistent with the intent and direction of both 49 CFR 211.51 and Executive Order 13563 of January 18, 2011 because it uses the best available science and technology to test new technologies and operational approaches and promotes innovation and competitiveness.

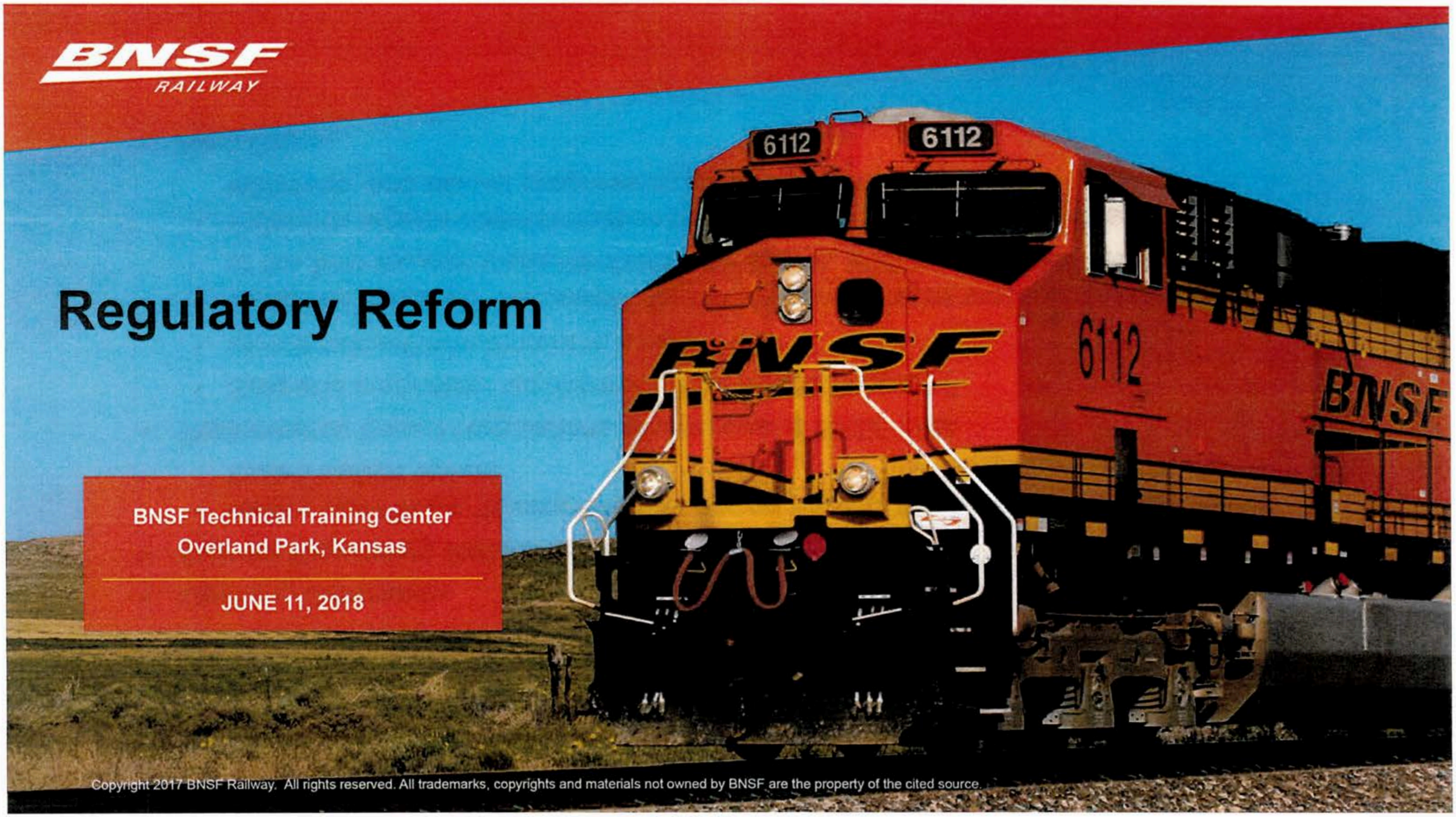
BNSF believes that a public hearing as described in 49 CFR 211 Subpart C is not required by statute, in light of the long-standing inspection waiver in place for the Long Island Railroad (LIRR). Upon successful completion of the test pilot for a period of approximately 6 months, BNSF anticipates filing a waiver that would allow for the processes developed during the test pilot to be rolled out system-wide, while maintaining the same communication structure developed during the test pilot.

Respectfully submitted,

BNSF Railway
2600 Lou Menk Dr
Fort Worth, Texas 76131

April 23, 2018

Exhibit 8



Regulatory Reform

BNSF Technical Training Center
Overland Park, Kansas

JUNE 11, 2018

Agenda Outline

- Opening Comments
- Current Regulatory Reform Initiatives
  - Heavy point frogs, ¾ concrete ties, flange bearing frogs, continuous rail testing, fouled ballast waiver
- Performance Based Regulations and proposed BNSF pilot
  - Suspend inspection requirements in 213.233 Subpart F
  - Identification/Commitment to a pilot area
  - Establish "roadbed" framework for reform opportunities that can be transitioned to the field for joint implementation, execution, and measurement/evaluation
  - Establish regular communication process for pilot progress updates, new initiatives, and waiver progression as appropriate
- Next Steps

BNSF-FRA Regulatory Partnership Opportunities

Engineering – Automated Inspections

- ***Problem Defined:***
- Current requirements create unnecessary exposure to MW employees performing track inspections that can be done more effectively via existing technology
- Regulations quantify defects and prescribe remedial action vs leveraging technology to advance preventive maintenance processes

- ***Vision / Idea Developed:***
- Dedicated inspection platform and subdivision segment(s) to demonstrate autonomous track inspection capabilities.
- Scalable to other segments of the railroad
- Suspend inspection requirements in 213.233 Subpart F
- Establish standards to allow layering of other performance based activities (e.g. rail inspection, safety, cwr & ballast maintenance, etc.)

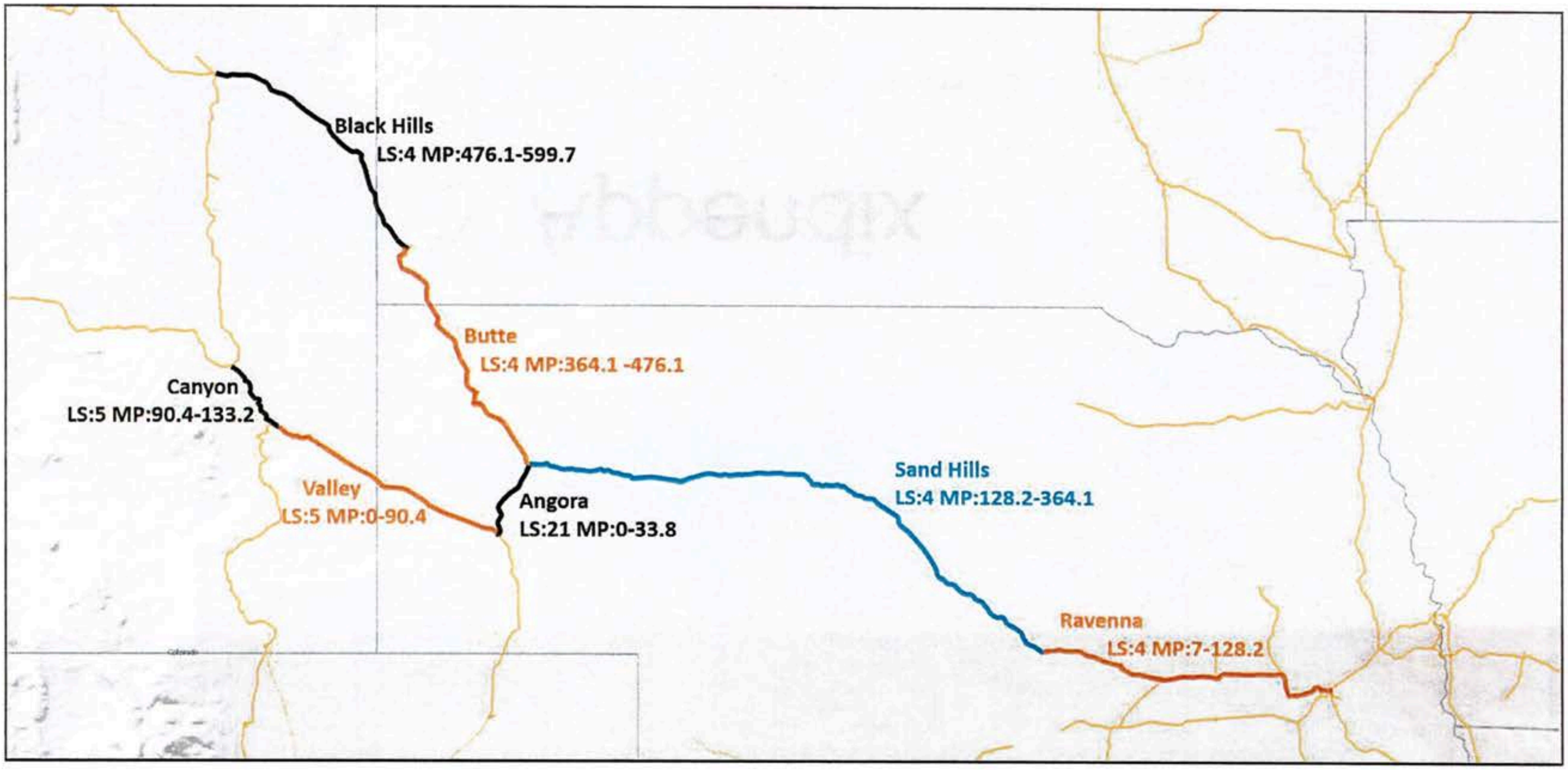
- **Measurement & Benefits:**
- Reduced safety exposures associated with on track hirail and walking inspections
- Higher quality inspection and defect detection, reducing service interruptions while supporting predictive vs reactive maintenance.
- Waiver facilitates development of next-level on board testing technology.

- **Plan / Timeline / Milestones:**
- 3-6 month test phase

Pilot Summary

- Leverage track inspection technology to enhance infrastructure integrity, mitigate inspector exposure, and improve freight capacity
- Select pilot territory to transition to a performance-based regulatory environment
- Partner with FRA to develop/evaluate inspection methods, frequencies, and track health metrics
- Establish “roadbed” at the senior level, allow the joint field teams to execute the development process
- Establish communication schedule/structure to monitor/discuss results, and adjust pilot processes as necessary, while providing a regular forum to present additional technology opportunities moving forward
- Progress pilot to waiver when appropriate, rolling out enhanced processes to other BNSF territories, maintaining “roadbed” and communication structure

Exhibit A pilot proposal map



Appendix

Future of Track Inspection

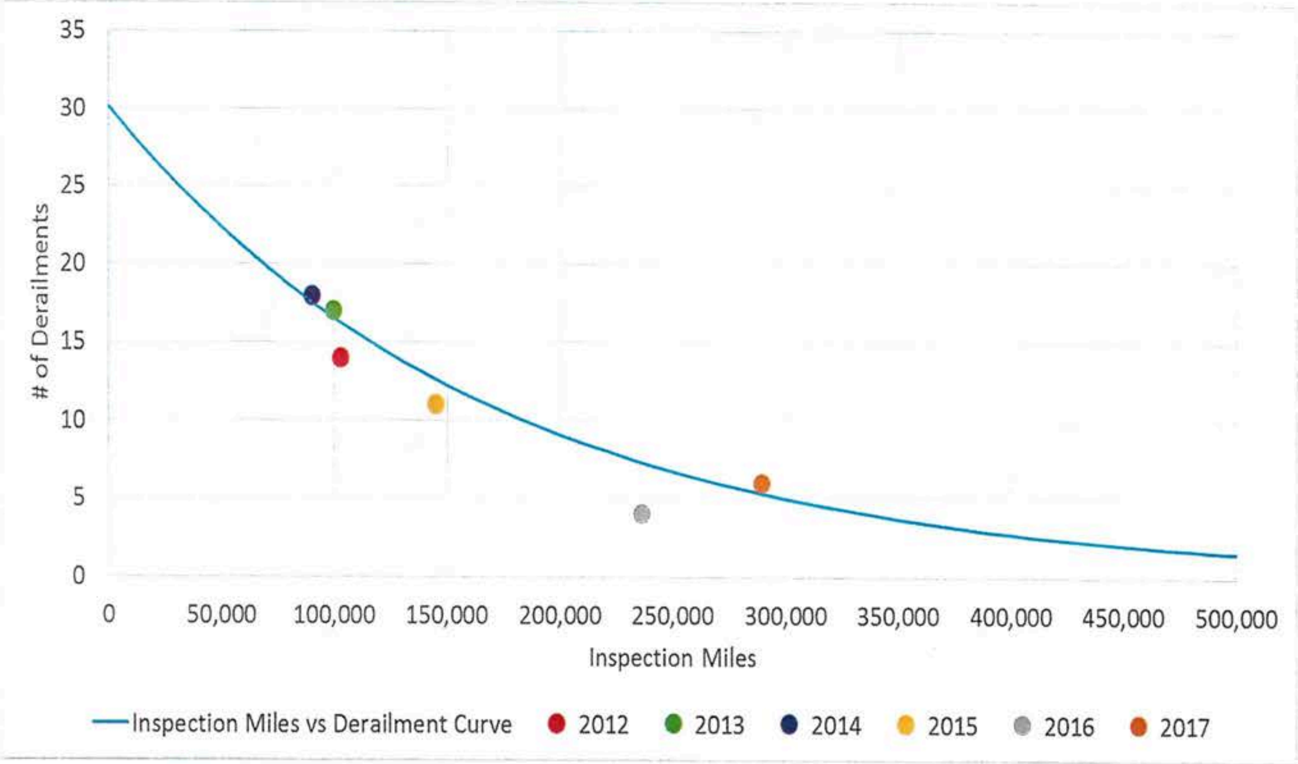
Future of Track Inspection

"A periodic, performance-based use of advanced inspection methods can improve the identification of existing track conditions and their deficiencies. The data achieved by the use of these technologies will enable the track inspector to more effectively verify and focus on the identified track anomalies; monitor those track segments bordering on potential defects; perform routine right-of-way property inspection for unsafe conditions; perform emergency and special inspections; perform emergency repairs and/or take appropriate remedial action in a timely manner; and, monitor the results of track work performed or in progress.

Railroads with the vision to invest in new technologies to better inspect and detect defects in the track structure should be provided the opportunity to modify the current visual inspection requirements."

NTSB Safety Recommendation 9/24/97

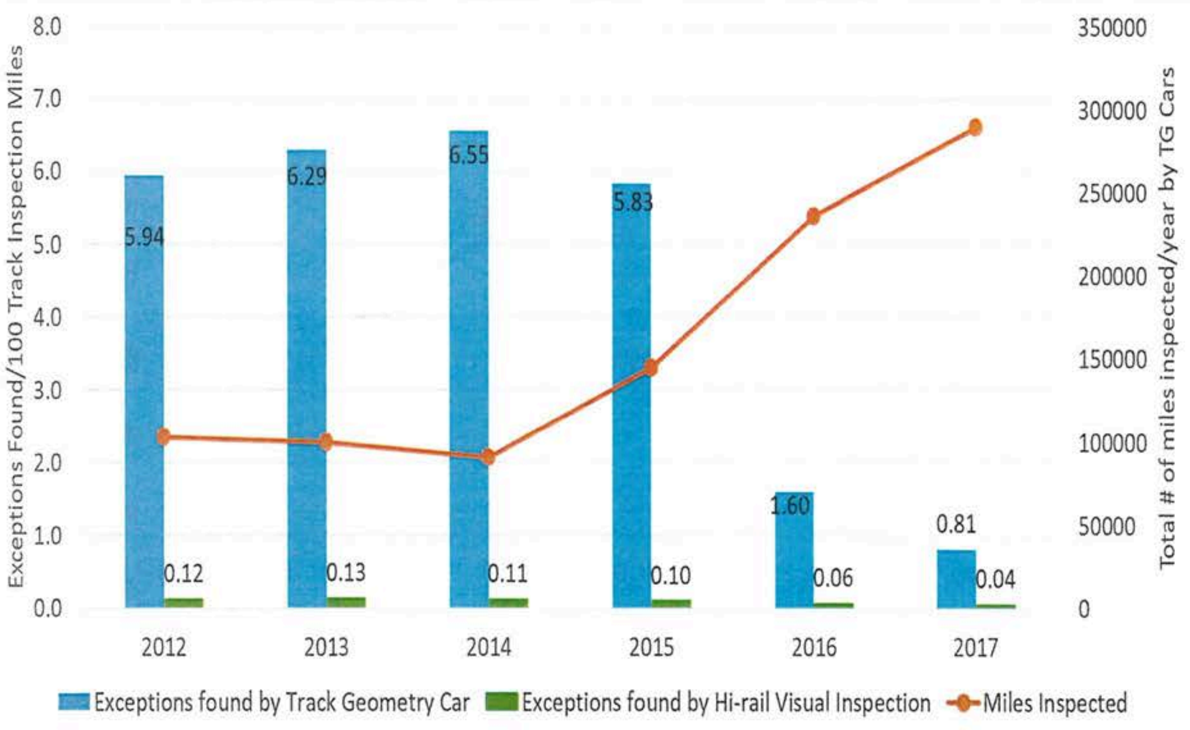
Effective Inspections Utilizing Data



Track Geometry Car Inspection Miles & Number of Derailments

- Mainline Track Caused Derailments Only T001-T199
- Gage, Alignment & Surface Exceptions

Correlation Between Geo Inspection Miles & Infrastructure Reliability

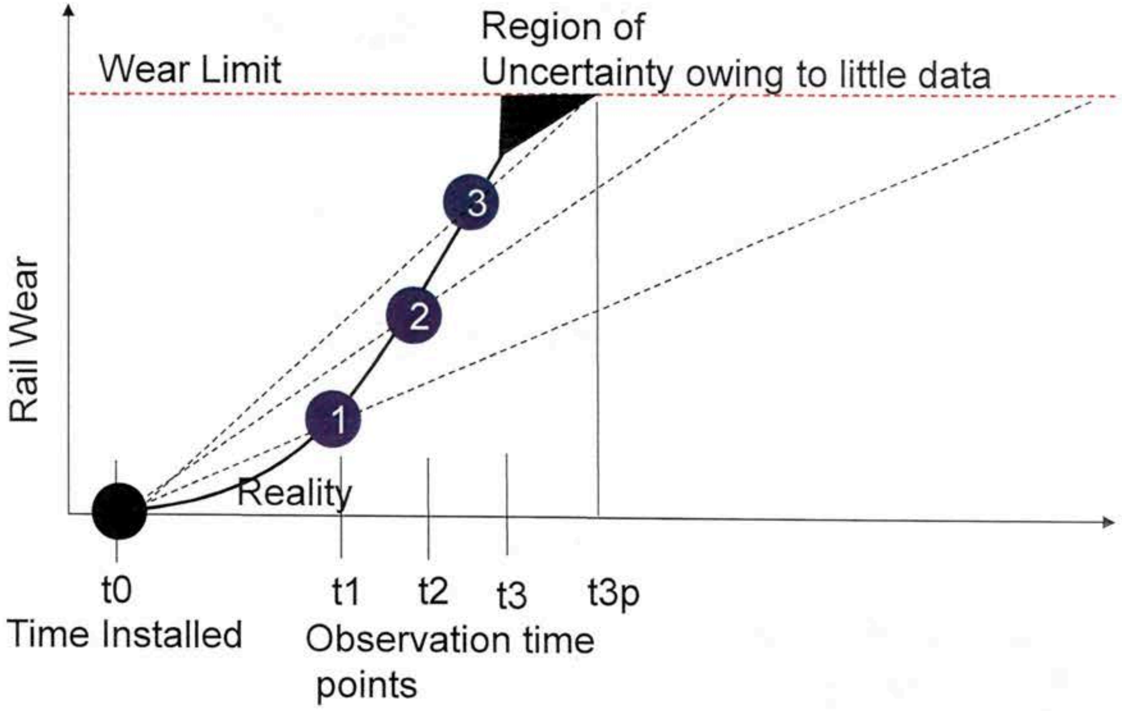


- Track Geometry Car Inspection Miles & Exceptions
  - All Railbound TG Car Inspections
  - Gage, Alignment & Surface Defects
- Increased inspections provides data to drive improved Capital Planning

Data Based Inspection Tools - Curve Model

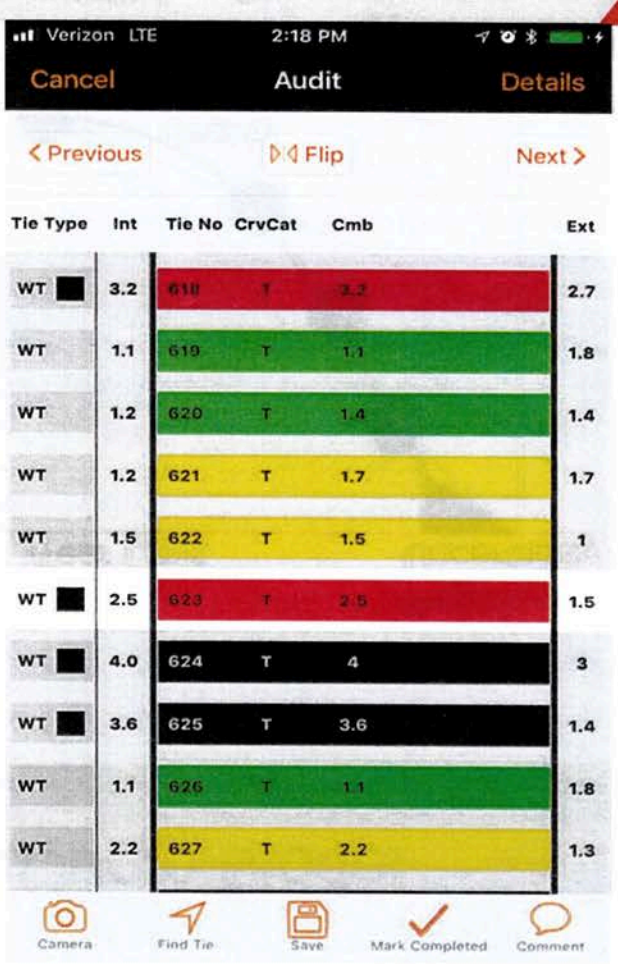
Predicts rail wear using regression modeling:

- Rail wear data from geometry car
- MGT
- Degree of Curvature
- Model is not linear, accommodates acceleration of wear

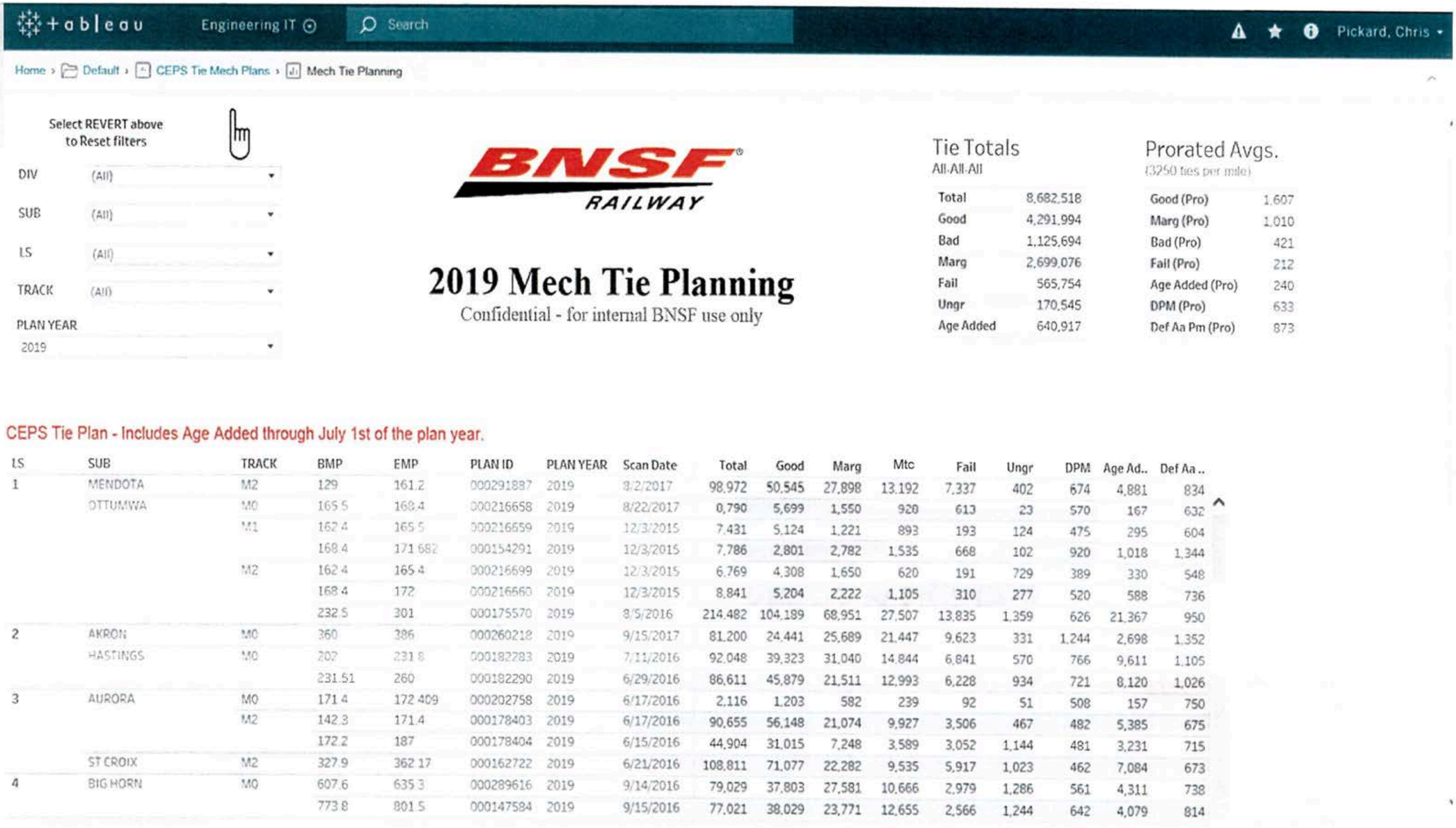


Tie Marking/Grading IPhone App

- Tie Type
- Int – Internal score
- Tie No - tie number in that mile
- CrvCat - T=Tangent, L=Light, M=Moderate, S=Severe
- Cmb - combined internal and external scores
- Ext - external score
- App allows for comments/pictures on any tie to include in your inspection



Tie Type	Int	Tie No	CrvCat	Cmb	Ext
WT ■	3.2	618	T	3.2	2.7
WT	1.1	619	T	1.1	1.8
WT	1.2	620	T	1.4	1.4
WT	1.2	621	T	1.7	1.7
WT	1.5	622	T	1.5	1
WT ■	2.5	623	T	2.5	1.5
WT ■	4.0	624	T	4	3
WT ■	3.6	625	T	3.6	1.4
WT	1.1	626	T	1.1	1.8
WT	2.2	627	T	2.2	1.3



Select REVERT above to Reset filters

DIV (All)

SUB (All)

LS (All)

TRACK (All)

PLAN YEAR 2019

2019 Mech Tie Planning

Confidential - for internal BNSF use only

Tie Totals

All-All-All

Total	8,682,518
Good	4,291,994
Bad	1,125,694
Marg	2,699,076
Fail	565,754
Ungr	170,545
Age Added	640,917

Prorated Avgs.

(3250 ties per mile)

Good (Pro)	1,607
Marg (Pro)	1,010
Bad (Pro)	421
Fail (Pro)	212
Age Added (Pro)	240
DPM (Pro)	633
Def Aa Pm (Pro)	873

CEPS Tie Plan - Includes Age Added through July 1st of the plan year.

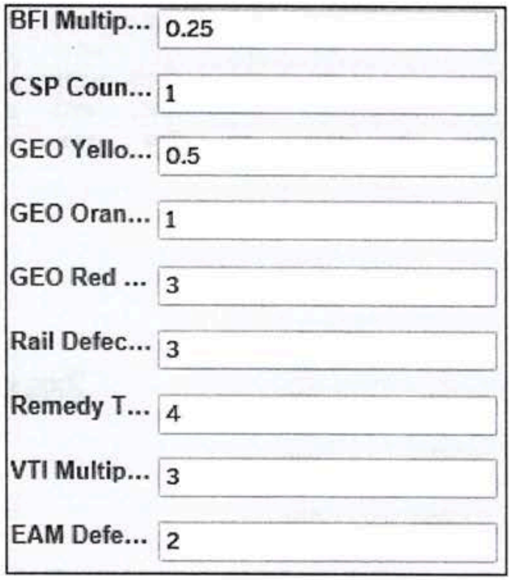
LS	SUB	TRACK	BMP	EMP	PLAN ID	PLAN YEAR	Scan Date	Total	Good	Marg	Mtc	Fail	Ungr	DPM	Age Ad..	Def Aa ..
1	MENDOTA	M2	129	161.2	000291887	2019	8/2/2017	98,972	50,545	27,898	13,192	7,337	402	674	4,881	834
	OTTUMWA	M0	165.5	168.4	000216658	2019	8/22/2017	0,790	5,699	1,550	920	613	23	570	167	632
		M1	162.4	165.5	000216659	2019	12/3/2015	7,431	5,124	1,221	893	193	124	475	295	604
			168.4	171.682	000154291	2019	12/3/2015	7,786	2,801	2,782	1,535	668	102	920	1,018	1,344
		M2	162.4	165.4	000216699	2019	12/3/2015	6,769	4,308	1,650	620	191	729	389	330	548
			168.4	172	000216660	2019	12/3/2015	8,841	5,204	2,222	1,105	310	277	520	588	736
			232.5	301	000175570	2019	8/5/2016	214,482	104,189	68,951	27,507	13,835	1,359	626	21,367	950
2	AKRON	M0	360	386	000260218	2019	9/15/2017	81,200	24,441	25,689	21,447	9,623	331	1,244	2,698	1,352
	HASTINGS	M0	202	231.8	000182283	2019	7/11/2016	92,048	39,323	31,040	14,844	6,841	570	766	9,611	1,105
			231.51	260	000182290	2019	6/29/2016	86,611	45,879	21,511	12,993	6,228	934	721	8,120	1,026
3	AURORA	M0	171.4	172.409	000202758	2019	6/17/2016	2,116	1,203	582	239	92	51	508	157	750
		M2	142.3	171.4	000178403	2019	6/17/2016	90,655	56,148	21,074	9,927	3,506	467	482	5,385	675
			172.2	187	000178404	2019	6/15/2016	44,904	31,015	7,248	3,589	3,052	1,144	481	3,231	715
	ST CROIX	M2	327.9	362.17	000162722	2019	6/21/2016	108,811	71,077	22,282	9,535	5,917	1,023	462	7,084	673
4	BIG HORN	M0	607.6	635.3	000289616	2019	9/14/2016	79,029	37,803	27,581	10,666	2,979	1,286	561	4,311	738
			773.8	801.5	000147584	2019	9/15/2016	77,021	38,029	23,771	12,655	2,566	1,244	642	4,079	814

Turnout Reliability

Model aggregates all pertinent condition data and includes;

- Inventory
- Ballast Fouling Index
- Comp Surf Plan
- Geo Tags
- Rail Defects
- Remedy Trouble Tickets
- VTI's
- EAM Reported Defects
- Maintenance Activities

Metric Weighting



BFI Multip... 0.25

CSP Coun... 1

GEO Yello... 0.5

GEO Oran... 1

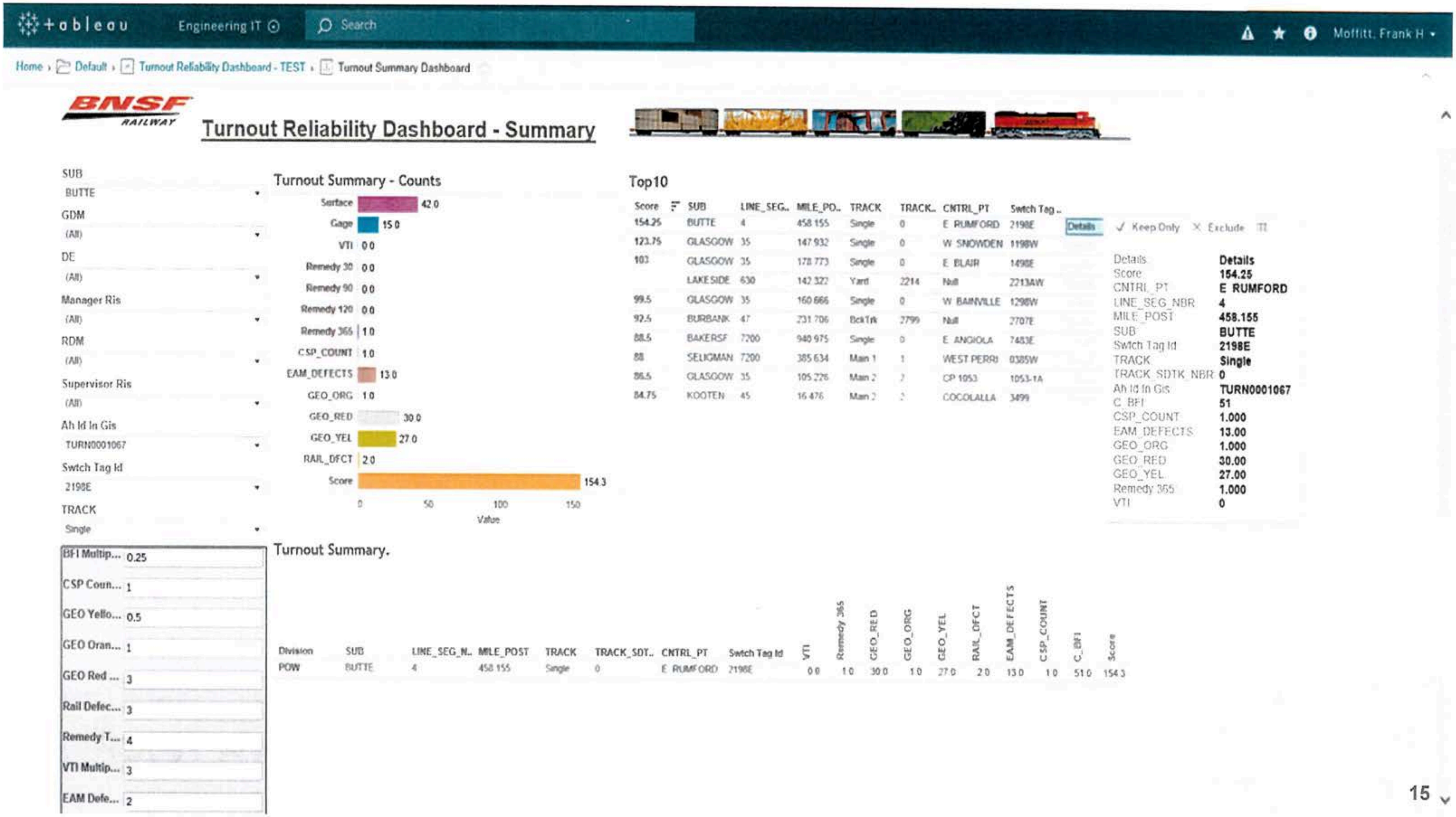
GEO Red ... 3

Rail Defec... 3

Remedy T... 4

VTI Multip... 3

EAM Defe... 2



Turnout Reliability Dashboard - Summary

SUB: BUTTE
GDM: (All)
DE: (All)
Manager Rls: (All)
RDM: (All)
Supervisor Rls: (All)
Ah Id In Gis: TURN0001067
Swtch Tag Id: 2198E
TRACK: Single

BFI Multip...: 0.25
CSP Coun...: 1
GEO Yello...: 0.5
GEO Oran...: 1
GEO Red ...: 3
Rail Defec...: 3
Remedy T...: 4
VTI Multip...: 3
EAM Defe...: 2

Turnout Summary - Counts

Top10

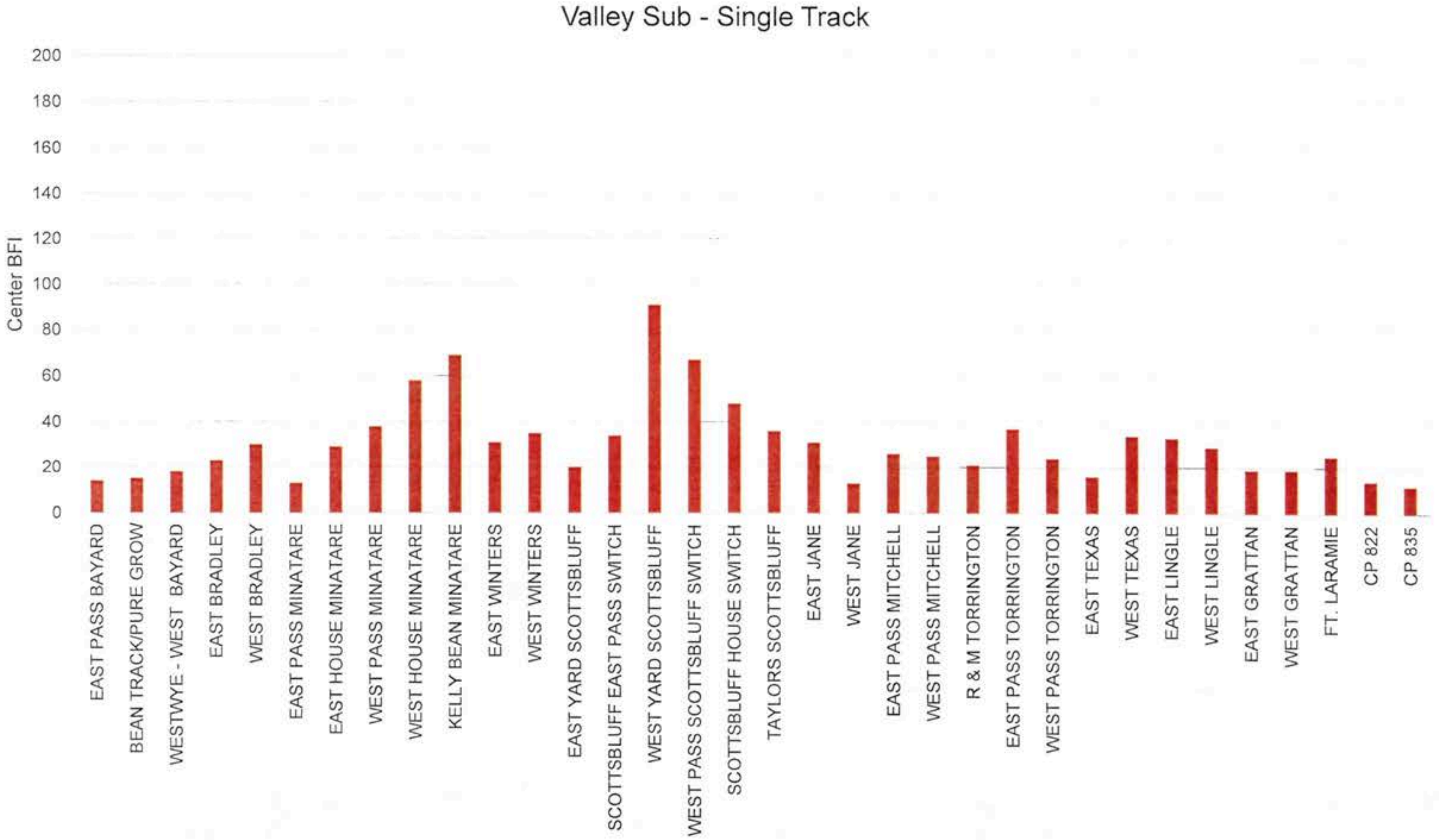
Score	SUB	LINE_SEG..	MILE_PO..	TRACK	TRACK..	CNTRL_PT	Swtch Tag ..
154.25	BUTTE	4	458.155	Single	0	E RUMFORD	2198E
123.75	GLASGOW	35	147.932	Single	0	W SNOWDEN	1198W
103	GLASGOW	35	178.773	Single	0	E BLAIR	1498E
	LAKESIDE	630	142.322	Yard	2214	Null	2213AW
99.5	GLASGOW	35	160.666	Single	0	W BAINVILLE	1298W
92.5	BURBANK	47	231.706	BckTrk	2799	Null	2707E
88.5	BAKERSF	7200	940.975	Single	0	E ANGIOLA	7483E
88	SELIGMAN	7200	385.634	Main 1	1	WEST PERRI	0385W
86.5	GLASGOW	35	105.226	Main 2	2	CP 1053	1053-1A
84.75	KOOTEN	45	16.476	Main 2	2	COCOLALLA	3499

Details	**Details**
Score	**154.25**
CNTRL_PT	**E RUMFORD**
LINE_SEG_NBR	**4**
MILE_POST	**458.155**
SUB	**BUTTE**
Swtch Tag Id	**2198E**
TRACK	**Single**
TRACK_SDTK_NBR	**0**
Ah Id In Gis	**TURN0001067**
C_BFI	**51**
CSP_COUNT	**1.000**
EAM_DEFECTS	**13.00**
GEO_ORG	**1.000**
GEO_RED	**30.00**
GEO_YEL	**27.00**
Remedy 365	**1.000**
VTI	**0**

Turnout Summary.

Division	SUB	LINE_SEG_N..	MILE_POST	TRACK	TRACK_SDT..	CNTRL_PT	Swtch Tag Id	VTI	Remedy 365	GEO_RED	GEO_ORG	GEO_YEL	RAIL_DFCT	EAM_DEFECTS	CSP_COUNT	C_BFI	Score
POW	BUTTE	4	458.155	Single	0	E RUMFORD	2198E	0.0	1.0	30.0	1.0	27.0	2.0	13.0	1.0	51.0	154.3

Center BFI – Valley Sub



Orange Tags – Predictive Analytics

Orange Tags are new exceptions developed to focus inspection and help prioritize surfacing behind a Geometry Car. Orange Tags represent track conditions that have higher priority than Yellow Tags but do not reach Red Tag limits.

How are Orange Tags determined?

Predictive analytics: surface Yellow Tags are evaluated based on an algorithm that predicts whether or not the tag will turn Red in 30 days. These include cross level, surface and alignment with warp soon to come.

By established exception limits: Defined Orange Tag limits have been established for Gage, Cant and Rail Wear exceptions. Gage and Cant are set at half the difference between Red and Yellow Tag limits.

Orange Tags must be inspected within three days following a Geo Car.

Comprehensive Surface Plan

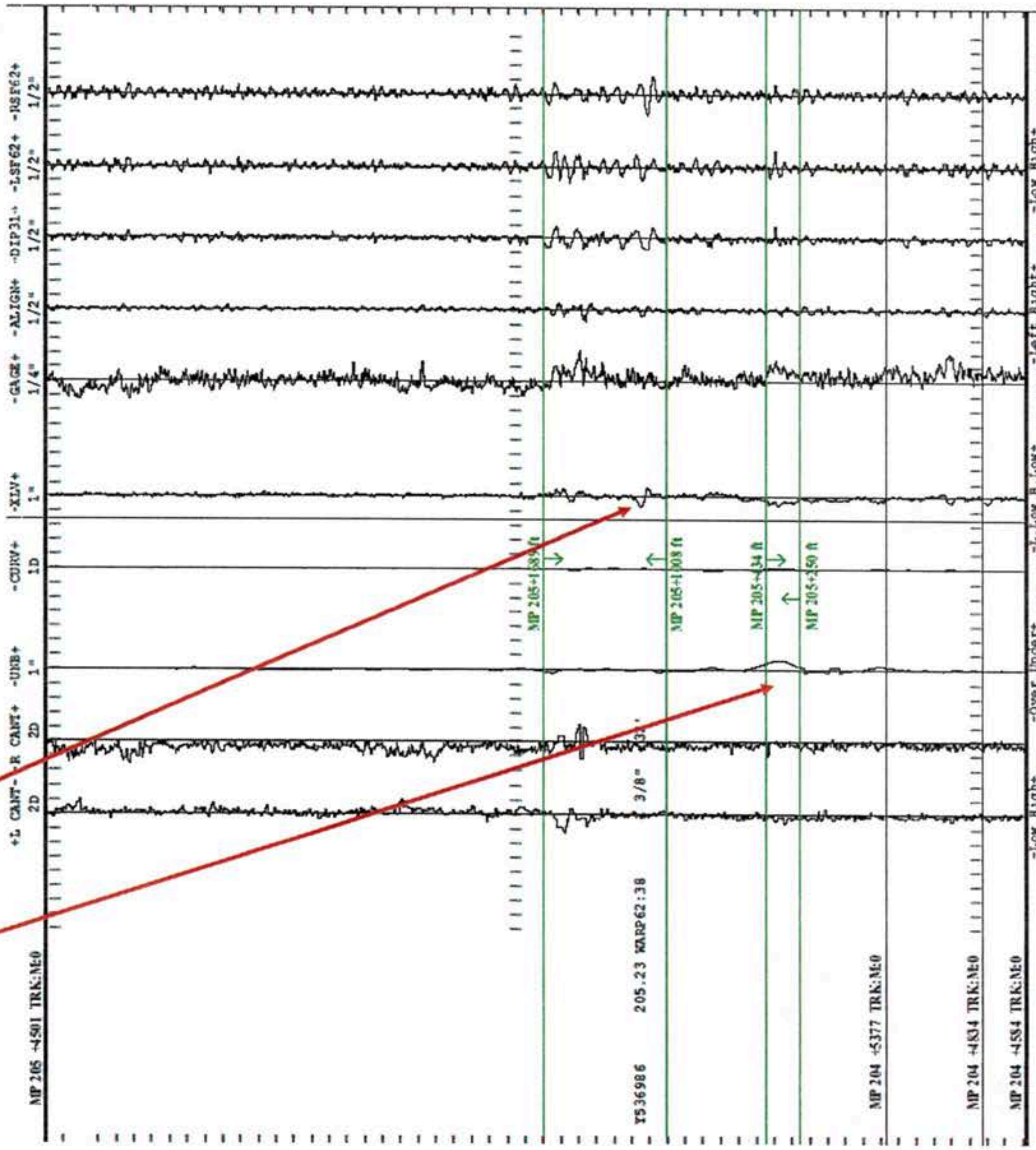
CSP was developed thru machine learning using foot by foot Geo data with additional rule sets.

Rule sets include;
crosslevel 5/8" > in Class 4 track, ½" > in Class 5. Curves over elevated 1">, surface1" >, alignment ½" >

It is post processed and available by 0900 the next day.

- Yellow Tag Exception of Warp for 32'
Total CSP at this location is 716'

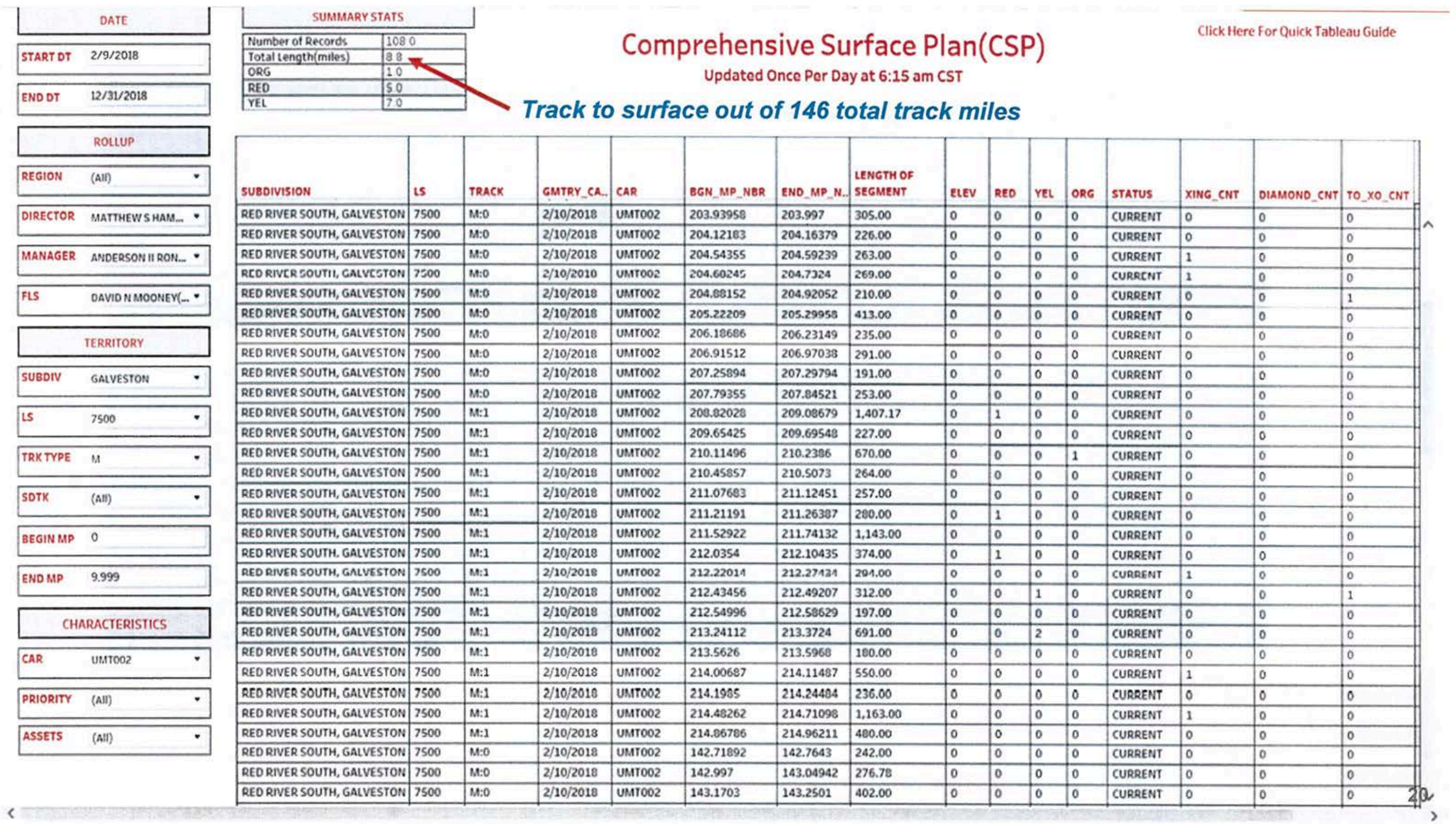
An Additional CSP is identified of 193' of track without any yellow, orange, or red tag exceptions.



Comprehensive Surfacing Plan Prioritization Model

Prioritization Mode	Window Requirements	Territory Recommendations	Type of Territory	Training
Mode 1 Firefighter	Leverage any window	Fallbridge	Single Track/CTC	Wk Feb 26th
		Galveston	Single Track/CTC	Wk Feb 19th
Mode 2 Reactive	Leverage large windows when available– Prod gang, surfacing, welding etc.	Marceline	Double Track/CTC	Late Feb
		Lampasas	Single Track/CTC	Wk March 1st
Mode 3 Proactive	Surfacing is the anchor window	Dickinson	Single Track	Wk March 19th
Mode 4 Hybrid Pro/F.F.	Surfacing is anchor/leverage any window* *Two tampers, one in Mode 1, 1 in mode 3	Hannibal	Single Track	Early March

Priority Levels	
Mode 1	All CSP segments with red and orange tags
Mode 2	All CSP segments with red and orange tags plus yellow tags, curves with reverse crosslevel and curves over elevated by ≥ 1.5"
Mode 3	All CSP segments, includes all above plus curves over elevated by ≥ 1"
All Modes	*Influence prioritization by including or excluding assets (turnouts and road crossings), for example, Proactive minus could be all CSP segments excluding turnouts and crossings w/o a geo tag.*



Comprehensive Surface Plan(CSP)

Updated Once Per Day at 6:15 am CST

Click Here For Quick Tableau Guide

Track to surface out of 146 total track miles

DATE

START DT 2/9/2018

END DT 12/31/2018

ROLLUP

REGION (All)

DIRECTOR MATTHEW S HAM...

MANAGER ANDERSON II RON...

FLS DAVID N MOONEY(...

TERRITORY

SUBDIV GALVESTON

LS 7500

TRK TYPE M

SDTK (All)

BEGIN MP 0

END MP 9.999

CHARACTERISTICS

CAR UMT002

PRIORITY (All)

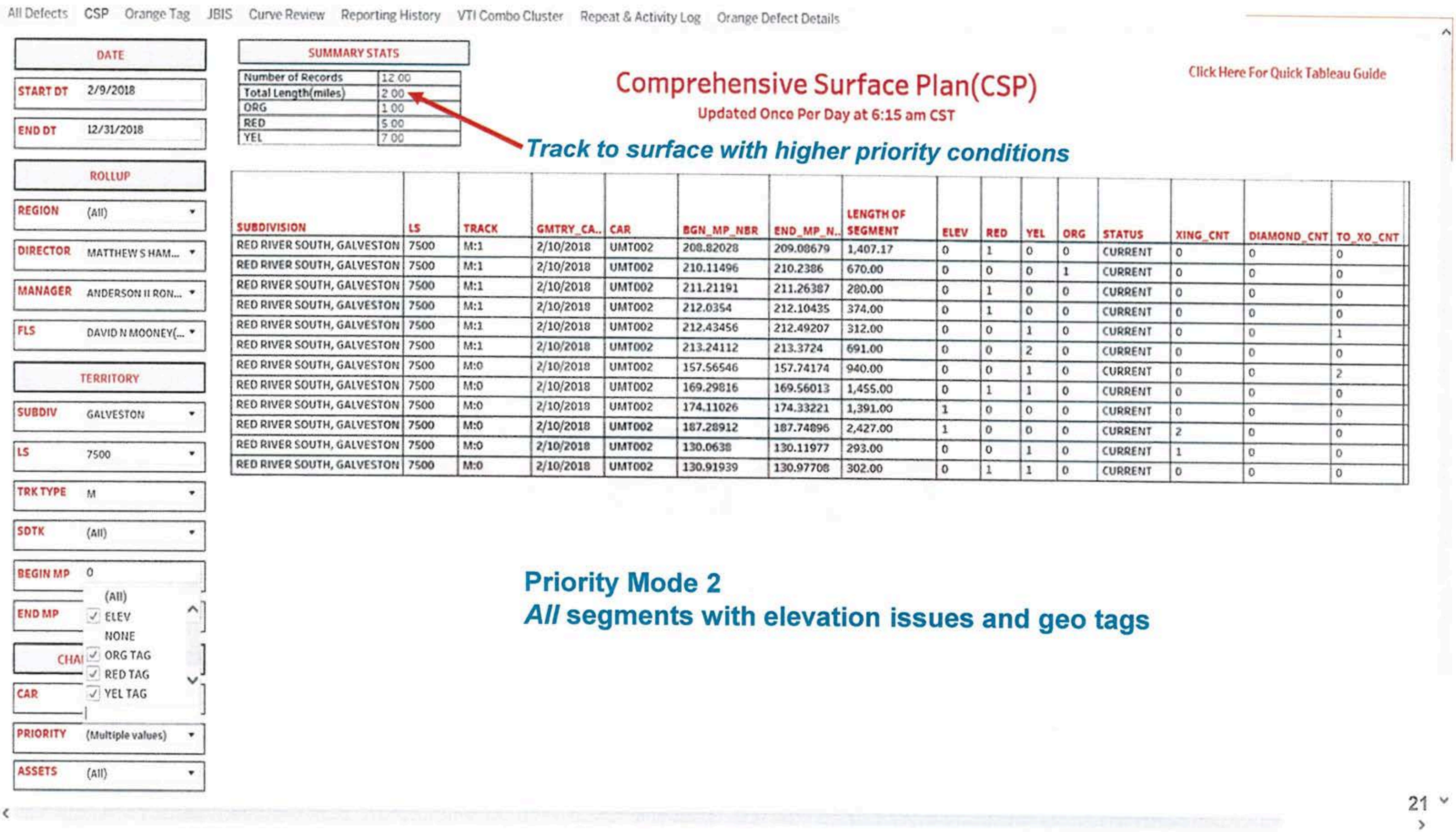
ASSETS (All)

SUMMARY STATS

Number of Records	108 0
Total Length(miles)	8 8
ORG	1 0
RED	5 0
YEL	7 0

SUBDIVISION	LS	TRACK	GMTRY_CA..	CAR	BGN_MP_NBR	END_MP_N..	LENGTH OF SEGMENT	ELEV	RED	YEL	ORG	STATUS	XING_CNT	DIAMOND_CNT	TO_XO_CNT
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	203.93958	203.997	305.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.12183	204.16379	226.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.54355	204.59239	263.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.60245	204.7324	269.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	204.88152	204.92052	210.00	0	0	0	0	CURRENT	0	0	1
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	205.22209	205.29958	413.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	206.18686	206.23149	235.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	206.91512	206.97038	291.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	207.25894	207.29794	191.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	207.79355	207.84521	253.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	208.82028	209.08679	1,407.17	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	209.65425	209.69548	227.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	210.11496	210.2386	670.00	0	0	0	1	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	210.45857	210.5073	264.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.07683	211.12451	257.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.21191	211.26387	280.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.52922	211.74132	1,143.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.0354	212.10435	374.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.22014	212.27434	294.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.43456	212.49207	312.00	0	0	1	0	CURRENT	0	0	1
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.54996	212.58629	197.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	213.24112	213.3724	691.00	0	0	2	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	213.5626	213.5968	180.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.00687	214.11487	550.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.1985	214.24484	236.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.48262	214.71098	1,163.00	0	0	0	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	214.86786	214.96211	480.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	142.71892	142.7643	242.00	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	142.997	143.04942	276.78	0	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	143.1703	143.2501	402.00	0	0	0	0	CURRENT	0	0	0

20



DATE

START DT 2/9/2018

END DT 12/31/2018

ROLLUP

REGION (All)

DIRECTOR MATTHEW S HAM...

MANAGER ANDERSON II RON...

FLS DAVID N MOONEY(...

TERRITORY

SUBDIV GALVESTON

LS 7500

TRK TYPE M

SDTK (All)

BEGIN MP 0

END MP

CHA

CAR

- (All)
- ☑ ELEV
- ☐ NONE
- ☑ ORG TAG
- ☑ RED TAG
- ☑ YEL TAG

PRIORITY (Multiple values)

ASSETS (All)

SUMMARY STATS

Number of Records	12.00
Total Length(miles)	2.00
ORG	1.00
RED	5.00
YEL	7.00

Comprehensive Surface Plan(CSP)

Updated Once Per Day at 6:15 am CST

Track to surface with higher priority conditions

SUBDIVISION	LS	TRACK	GMTRY_CA..	CAR	BGN_MP_NBR	END_MP_N..	LENGTH OF SEGMENT	ELEV	RED	YEL	ORG	STATUS	XING_CNT	DIAMOND_CNT	TO_XO_CNT
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	208.82028	209.08679	1,407.17	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	210.11496	210.2386	670.00	0	0	0	1	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	211.21191	211.26387	280.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.0354	212.10435	374.00	0	1	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	212.43456	212.49207	312.00	0	0	1	0	CURRENT	0	0	1
RED RIVER SOUTH, GALVESTON	7500	M:1	2/10/2018	UMT002	213.24112	213.3724	691.00	0	0	2	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	157.56546	157.74174	940.00	0	0	1	0	CURRENT	0	0	2
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	169.29816	169.56013	1,455.00	0	1	1	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	174.11026	174.33221	1,391.00	1	0	0	0	CURRENT	0	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	187.28912	187.74896	2,427.00	1	0	0	0	CURRENT	2	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	130.0638	130.11977	293.00	0	0	1	0	CURRENT	1	0	0
RED RIVER SOUTH, GALVESTON	7500	M:0	2/10/2018	UMT002	130.91939	130.97708	302.00	0	1	1	0	CURRENT	0	0	0

Priority Mode 2

***All* segments with elevation issues and geo tags**

BNSF®
RAILWAY

BEFORE THE FEDERAL RAILROAD ADMINISTRATION

PETITION FOR A TEMPORARY SUSPENSION OF 49 C.F.R. § 213.233 TO ALLOW FOR THE TESTING OF AUTOMATED TRACK INSPECTION METHODOLOGIES

SUBMITTED BY
BNSF Railway

Pursuant to 49 C. F.R. § 211.51, BNSF Railway (BNSF), submits the following petition for a temporary suspension of 49 C.F.R. § 213.233 to allow it to test automated track inspection methodologies that will leverage technologies to enhance infrastructure integrity, reduce inspector exposure associated with track hi-rail and walking inspections, improve quality and defect detection, and enhance freight capacity. Section 211.51 allows BNSF to petition FRA for a temporary suspension of these requirements to permit a pilot program conducted on a segment of the BNSF system to demonstrate the use of such technologies.

Performing manual visual hi-rail track inspection creates unnecessary exposure to maintenance-of-way employees, given the ability to use technology to accomplish the same task. Periodic, performance-based use of one or more of these available advanced inspection methods provides a record of continuous measurable data for the actual track conditions, and offers a more consistent and comprehensive evaluation of track infrastructure integrity. Measuring the track, under load and at track speed, and creating an accurate record of each inspection, also facilitates the use of data analytics to create a predictive vs reactive maintenance environment. It will improve the identification of existing track conditions and their deficiencies, enabling track inspectors and maintenance of way employees to more effectively verify and focus on the identified track anomalies, address any defects found by the automated inspection, proactively schedule preventative maintenance activities before locations progress to defects, and make more efficient use of their inspection resources.

BNSF proposes to establish an automated track inspection pilot program with the following parameters:

1. BNSF's initial pilot location will involve portions of main track and sidings on the Ravenna, Sand Hills, Butte, Black Hills, Canyon, Valley and Angora subdivisions on the Powder River Division. See Exhibit A for map of the proposed area.
2. BNSF intends to utilize a phased implementation approach, increasing automated testing frequency while evaluating appropriate supplemental manual inspection parameters.
3. Identification and evaluation of performance-based track health metrics will be utilized to determine effectiveness of the automated inspection program. BNSF proposes initial performance metric of verified track safety defects per 100 test miles, not appropriately protected for track class.
4. Appropriate adjustment of the pilot processes will be made, as necessary, based on review of the results obtained during the test pilot and discussions with FRA leadership concerning other available technologies.

The FRA has recognized the benefits of automated track inspection technology in 1975 when it waived requirements of § 213.233 and allowed Long Island Railroad to utilize track geometry cars (TGCs) to supplement manual visual inspections.[1] Over the course of the last four decades, automated track inspection technologies have continued to advance, and new technologies have been developed that surpass what can be detected with manual visual hi-rail inspection processes. For example, laser vision systems with backscatter x-ray technology drives tie replacement, ground penetrating radar drives ballast renewal programs, "run-over-run" big data analytics drives track surfacing programs, Vehicle track interaction (VTI)-equipped locomotives measure and monitor track/car dynamics, and automated optical systems use machine learning to detect potential defects. Advancements in high precision GPS mapping, data storage and processing speeds, and overall network connectivity allow TGCs to run in unmanned mode dramatically increasing productivity and the volume of track health data produced. BNSF data scientists use the track health data working with our field subject matter experts to develop algorithms and predictive models which then drive maintenance activities.

This test pilot is consistent with the intent and direction of both 49 CFR 211.51 and Executive Order 13563 of January 18, 2011 because it uses the best available science and technology to test new technologies and operational approaches and promotes innovation and competitiveness.

BNSF believes that a public hearing as described in 49 CFR 211 Subpart C is not required by statute, in light of the long-standing inspection waiver in place for the Long Island Railroad (LIRR). Upon successful completion of the test pilot for a period of approximately 6 months, BNSF anticipates filing a waiver that would allow for the processes developed during the test pilot to be rolled out system-wide, while maintaining the same communication structure developed during the test pilot.

Respectfully submitted,

BNSF Railway
2600 Lou Menk Dr
Fort Worth, Texas 76131

June 8, 2018

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[1] This waiver remains in place today.

Exhibit 9

U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

JUL 0 5 2018

Steve Anderson
Vice President, Engineering
BNSF Railway Company
2600 Lou Menk Drive
Fort Worth, TX 76131

RE: PETITION FOR A TEMPORARY SUSPENSION OF 49 C.F.R. § 213.233

Dear Mr. Anderson,

This response is in reply to BNSF Railway's (BNSF) draft Petition for the Federal Railroad Administration (FRA) to temporarily suspend 49 C.F.R. § 213.233 for it to test automated track inspection methodologies. BNSF presented its draft proposal to FRA during an April 24, 2018, meeting at FRA Headquarters in Washington, DC. BNSF's draft petition requests that FRA temporarily suspend, under 49 C.F.R. § 211.51 (Section 211.51), compliance with 49 C.F.R. § 213.233 so that it can conduct a pilot program on a portion of BNSF's Powder River Division main line and siding tracks—a combined distance of approximately 766 miles.

In its draft petition, BNSF proposes four general testing parameters, including identification of the initial geographic bounds of the proposed pilot program and other general strategies and goals for the proposed pilot project (e.g., phased implementation of automated testing, identification, evaluation of performance-based track health metrics, and adjustment of the pilot process as necessary).

Section 211.51 authorizes the FRA Administrator to temporarily suspend the application of a safety regulation such as 49 C.F.R. § 213.233 if the suspension "is necessary to the conduct of a Federal Railroad Administration approved test program designed to evaluate the effectiveness of new technology or operational approaches." 49 C.F.R. § 211.51(a)(1). The section further requires any such suspension to be "limited in scope" as may be necessary to facilitate the conduct of the test program, and be "conditioned on the observance of standards sufficient to assure safety." 49 C.F.R. § 211.51(a)(2)–(3).

Thus, the first step to enabling FRA to suspend its existing regulations to enable BNSF to conduct its proposed pilot is the development of a test program designed to evaluate the effectiveness of the technology to be tested and, at the same time, assure the safety of the testing. The four general testing parameters BNSF set forth in its draft petition lack sufficient detail to constitute a test program as Section 211.51 requires. To aid BNSF in developing such a program, FRA believes inclusion of the following information would be helpful:

1. Identification of the track characteristics for the segments that will be included in the test program, including maps illustrating tonnage, tangent and curve information, timetable and operating authority, track classes, and start and end mileposts;

2. A list of the yards that fall within the designated test program territory and the type of inspection method that will be used to ensure compliance with the Part 213 Track Safety Standards (other than 49 CFR § 231.233);

3. Identification of the specific technologies that BNSF will test and how those technologies will be employed to address the safety requirements and detect defects for each of the following Part 213 sections: .33, .37, .53, .55, .57, .59, .63, .65, .103, .109, .110 (only if applicable), .115, .121, .123, .127, .137, .139 (if any), .141, and .143;

4. If technologies are not readily available to address some of the components listed in (3), how BNSF will inspect and ensure the safety of these components;

5. If the employed technology does not cover all segments in multiple track territory, the program needs to specify how to make up the missed inspection;

6. Specific procedures for verifying and remediating suspected defects, including how soon a suspected defect must be verified; and

7. Procedures for how data will be transmitted, processed, managed, stored and how the data will be translated into usable results.

The above list is intended to provide guidance in BNSF's development of a test program. FRA appreciates and supports BNSF's initiative to identify advanced track inspection methods utilizing new technologies and stands ready to assist BNSF in finalizing its proposed test program.

Sincerely,

for Robert E. Lauby
Associate Administrator Railroad Safety
Chief Safety Officer

Exhibit 10

BEFORE THE FEDERAL RAILROAD ADMINISTRATION

PETITION FOR A TEMPORARY SUSPENSION OF 49 C.F.R. § 213.233(b) and (c) TO ALLOW FOR THE TESTING OF AUTOMATED TRACK INSPECTION METHODOLOGIES

SUBMITTED BY
BNSF Railway

Pursuant to 49 C. F.R. § 211.51, BNSF Railway (BNSF), submits the following petition for a temporary suspension of 49 C.F.R. § 213.233 (b) requiring inspections to be made on foot or by riding over track in a vehicle at speed that allows the person making the inspection to visually inspect the track structure and 49 C.F.R. § 213.233 (c) requiring twice weekly inspections to allow it to test automated track inspection methodologies on main track and sidings that will leverage technologies to enhance infrastructure integrity, reduce inspector exposure associated with track hi-rail and walking inspections, improve quality and defect detection, and enhance freight capacity.

Section 211.51 allows BNSF to petition FRA for a temporary suspension of these requirements to permit a pilot program conducted on a segment of the BNSF system to demonstrate the use of such technologies.

Performing manual visual hi-rail track inspection creates unnecessary exposure to maintenance-of-way employees, given the ability to use technology to accomplish the same task. Periodic, performance-based use of one or more of these available advanced inspection methods provides a record of continuous measurable data for the actual track conditions, and offers a more consistent and comprehensive evaluation of track infrastructure integrity. Measuring the track, under load and at track speed, and creating an accurate record of each inspection, also facilitates the use of data analytics to create a predictive vs reactive maintenance environment. It will improve the identification of existing track conditions and their deficiencies, enabling track inspectors and maintenance of way employees to more effectively verify and focus on the identified track anomalies, address any defects found by the automated inspection, proactively schedule preventative maintenance activities before locations progress to defects, and make more efficient use of their inspection resources.

BNSF will establish an automated track inspection pilot program with the following parameters:

1. BNSF's initial pilot location will involve portions of main track and sidings on the Ravenna, Sand Hills, Butte, Black Hills, Canyon, Valley and Angora subdivisions on the Powder River Division. The pilot territory will not include yard or back tracks on the route. See Exhibit A for maps, track charts, and tonnage information of the proposed area.
2. BNSF intends to utilize a phased implementation approach of various track inspection technologies, as set forth in Exhibit B, increasing automated testing frequency while evaluating appropriate supplemental manual inspection parameters. Segments of track that are missed on the prescribed phasing plan will be inspected via manual hi-rail inspection.
3. The pilot program will be designed to specifically test the unmanned automated track

geometry car for track inspection as a viable alternative to manual, visual inspection. The pilot will also include testing of an optical visual platform in Phase 3 (see Exhibit B). BNSF will continue to employ other technologies that supplement manual, visual inspection, including: ground penetrating radar, Vehicle Track Interaction (VTI) technology, Aurora cars, and ultrasonic rail detection. These technologies, in combination with twice monthly manual, visual hi-rail inspections will allow BNSF to address the safety requirements and detect defects associated with the components of Part 213.

4. Performance-based track health metrics will be utilized to determine effectiveness of the automated inspection program. BNSF will use 2014 data, which is the last year before BNSF implemented autonomous testing, as a baseline for track geometry defects per 100 miles. BNSF will test various frequencies of automated inspection to maintain a rate of track safety defects per 100 miles that is at or below 5.0 track geometry defects per 100 miles identified in the baseline. Exception reports generated will be reviewed and field-verified within 48 hours and remediated immediately upon validation.
5. Consistent with current processes, manual, visual inspections and defects associated with those inspections will be reported through BNSF's EAM system. BNSF will submit reports on a monthly basis during the pilot detailing the results of the testing, including red tags defects identified and the remediation associated with each defect.
6. Appropriate adjustment of the pilot processes will be made, as necessary, based on review of the results obtained during the test pilot and discussions with FRA leadership concerning other available technologies.

The FRA has recognized the benefits of automated track inspection technology in 1975 when it waived requirements of § 213.233(c) and allowed Long Island Railroad to utilize track geometry cars (TGCs) to supplement manual visual inspections. [1] Over the course of the last four decades, automated track inspection technologies have continued to advance, and new technologies have been developed that surpass what can be detected with manual visual hi-rail inspection processes. For example, laser vision systems with backscatter x-ray technology drives tie replacement, ground penetrating radar drives ballast renewal programs, "run-over-run" big data analytics drives track surfacing programs, Vehicle track interaction (VTI)-equipped locomotives measure and monitor track/car dynamics, and automated optical systems use machine learning to detect potential defects. Advancements in high precision GPS mapping, data storage and processing speeds, and overall network connectivity allow TGCs to run in unmanned mode dramatically increasing productivity and the volume of track health data produced. BNSF data scientists use the track health data working with our field subject matter experts to develop algorithms and predictive models which then drive maintenance activities.

This test pilot is consistent with the intent and direction of both 49 CFR 211.51 and Executive Order 13563 of January 18, 2011 because it uses the best available science and technology to test new technologies and operational approaches and promotes innovation and competitiveness.

BNSF believes that a public hearing as described in 49 CFR 211 Subpart C is not required by statute, in light of the long-standing inspection waiver in place for the Long Island Railroad (LIRR). Upon successful completion of the test pilot for a period of approximately 12 months, BNSF anticipates filing a waiver that would allow for the processes developed during

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[1] This waiver remains in place today.

the test pilot to be rolled out system-wide, while maintaining the same communication structure developed during the test pilot.

Respectfully submitted,

Tamara R Middleton

BNSF Railway
2600 Lou Menk Dr
Fort Worth, Texas 76131

July 31, 2018

EXHIBIT A

Pilot Territory Description

Main and siding tracks only going from Lincoln, NE and Donkey Creek, WY and back to Lincoln, NE via BNSF's Coal Loop excluding the Orin subdivision.

MP Ranges by Subdivision:

- Ravenna Sub from MP 11.082 to MP 128.200
- Sand Hills Sub from MP 128.2 to 364.1
- Butte Sub from MP 364.1 to MP 476.1
- Black Hills Sub from MP 476.1 to MP 586.286
- Canyon Sub from MP 90.4 to MP 133.2
- Valley Sub from MP 0.00 to MP 90.4
- Angora Sub from MP 33.826 to MP .3

Total Route Miles: 1,040

Territory Characteristics

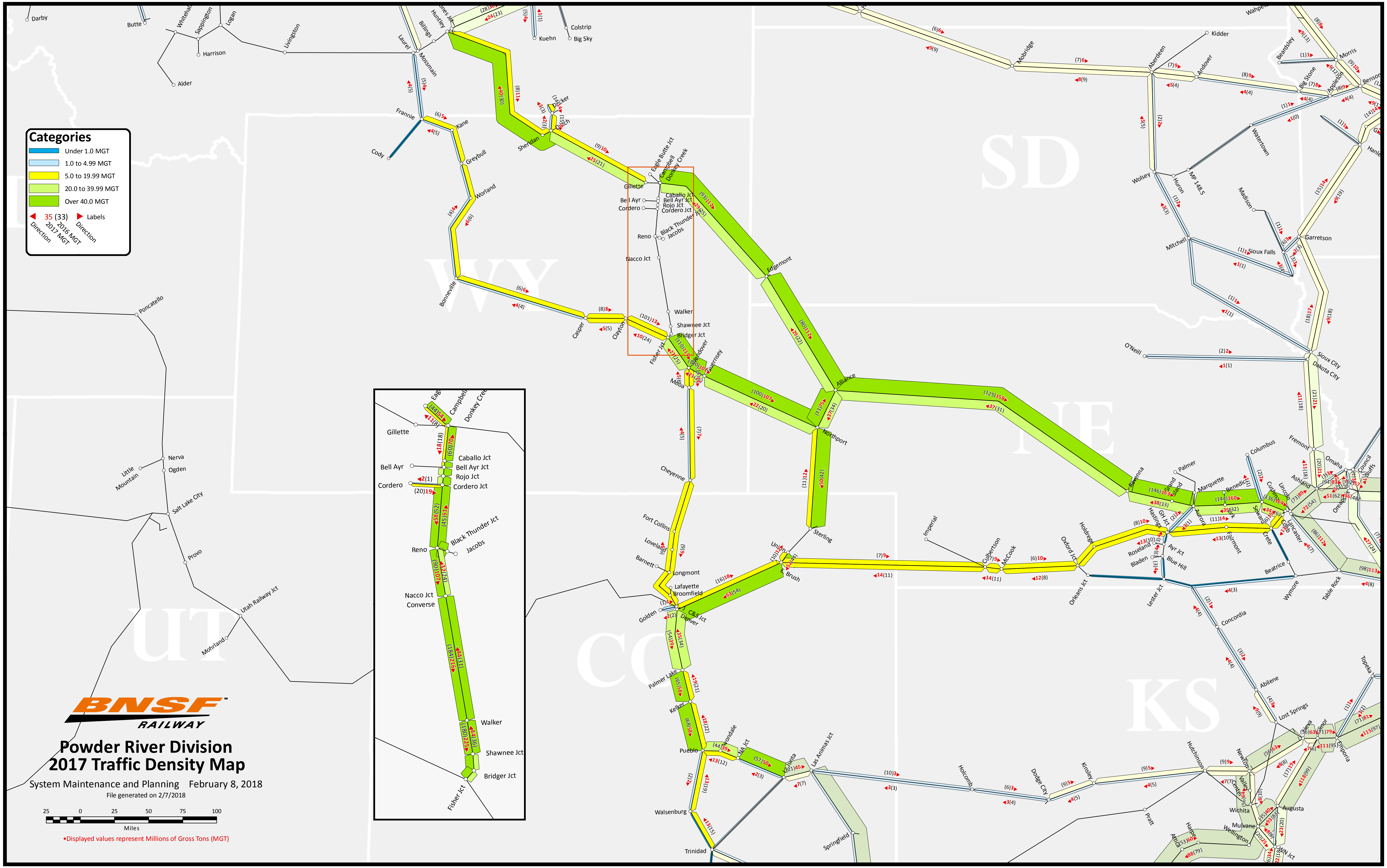
- The primary traffic is coal; there is some manifest and intermodal traffic
- Tonnage varies by subdivision with **105 MGT** on the Angora and **198 MGT** on the Sand Hills/Ravenna
- 55% concrete ties, 45% wood ties
- 156 miles of single track, the remainder is double track
- 1,348 miles total track mile require inspection (including both mains)
- 520 Control points, 292 bridges, and 598 turnouts
- Joint count averaged 0.4 first 3 months of 2018 (current count of 382 joints)
- Lincoln, NE is the biggest city on the route with 280,364 people (2016 estimate)
    - The next biggest town is Alliance, NE with 8,403 people (2016 estimate)
- Primarily Class 4 Railroad; Max speed loads - 50; Max speed empties – 60

Track Occupancy Associated with Manual Hy-rail inspections

21 Track Inspectors spread across several Roadmasters (excluding the Orin)

2016 - 31,453 authorities for 19,557 total hours of track occupancy

2017 – 30,246 authorities for 19,483 total hours of track occupancy



BNSF RAILWAY

Powder River Division
2017 Traffic Density Map

System Maintenance and Planning February 8, 2018

File generated on 2/7/2018

•Displayed values represent Millions of Gross Tons (MGT)

TOC Home

SOUTHWARD ↓	Length of Siding (Feet)	Station Nos.	Mile Post	Angora Subdivision MAIN LINE STATIONS	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.	↑ NORTHWARD
	Adjoining Sub: Butte Subdivision Boundary: Angora, MP 0.5 / Butte, MP 365.9 Information for Alliance Terminal is located in the Butte Sub Timetable								
			0.6	THIRD STREET Adj. Sub: Butte, MP 0.6	JX	CTC	21	0.6	
			0.9	SOUTH WYE	X			3.7	
	End Sterling Main MP 0.9 GCOR/MWOR 6.28 Governs between MP 0.9 and MP 4.4								
			4.6	SOUTH ALLIANCE	X(2)	CTC 2 MT	21	2.3	
		32007	6.9	LETAN	X			5.1	
			12.0	MP 12.0	X			1.8	
		32014	13.8	BONNER		CTC		3.5	
			17.3	NORTH ANGORA				3.8	
			21.1	MP 21.1	X(2)	CTC 2 MT		6.4	
			27.5	MP 27.5	X(2)			6.3	
		32034	33.8	NORTHPORT Adj. Sub: Valley, MP 33.8	JT			0.6	
			34.4	UP CROSSING Adj. RR: UP, MP 34.4	JM	CTC		2.1	
	7,117	84003	36.5	BRIDGEPORT				2.0	
			38.5	MP 38.5				5.7	
	7,119	84011	44.2	MUDD SPRINGS				12.2	
	7,118	84023	56.4	DALTON				5.9	
		84028	62.3	GURLEY				6.9	
	8,314	84035	69.2	HUNTSMAN	TX			6.2	
		84042	75.4	SIDNEY				7.6	
	7,116	84050	83.0	LORENZO				7.0	
	8,855	84056	90.0	PEETZ				8.3	
	7,105	84067	98.3	BUCHANAN				13.8	
			112.1	NORTH STERLING				3.0	
		84081	115.1	STERLING	JRT	RL		112.7	
	Adjoining Sub: Brush Subdivision Boundary: Angora, MP 115.1 / Brush, MP 115.1 Information for Sterling is located in the Brush Sub Timetable								

Mountain Continental Time in effect on Angora Subdivision

Radio Call-In

Radio Channel 070 in service at Alliance Yard

Radio Channel 054 in service:
Southward: S. Alliance to MP 107.0
Northward: Sterling to MP 12.0

Alliance S - 70(X)	Bridgeport - 71(X)	Huntsman - 72(X)

Peetz - 73(X)

UP DS Northport Channel 020 - Call-in *51

Radio Channel 040 in service Bridgeport to Sterling for switching

Radio Channel TX 091/RX 039 in service at Sterling Yard for switching - 63(X)

Guernsey Yardmaster - 636

Emergency - Call 911

Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3,
Railroad Police X=4, Detector Desk X=5, PTC Desk X=9

Dispatcher Information

Third Street to S. Wye—817-867-7078, Fax 817-352-7057
S. WYE to Sterling—817-867-7079, Fax 817-352-7060

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

	Frt	
Main Track	**Under 100 TOB**	**100 TOB & Over**
MP 0.3 to MP 0.9, Sterling Lead	20	20
MP 0.8 to MP 0.9, Sterling Main	20	20
MP 4.4 to MP 115.1	50	45
Other Tracks Where CTC is in Effect (GCOR/MWOR 10.0)		
MP 0.5 to MP 0.6, West lead	10	10
MP 0.3 to MP 0.9, West leg wye	10	10
MP 0.8 to MP 0.9, Tail track	10	10
MP 34.0 to MP 34.2, South leg wye	25	25
Northport, UP transfer track	10	10

Temperature Restrictions

Contact the train dispatcher if in doubt of the temperature. Notify the train dispatcher when the train is restricted.

MP 4.4 to MP 115.1, - 10 degrees F & under	45	30

1(B). Speed—Permanent Restrictions

	Frt
MP 24.4 to MP 30.2	45
MP 33.7 to MP 34.5	25
MP 34.5 to MP 36.7	35
MP 49.4 to MP 56.0	45
MP 74.0 to MP 75.0	40

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

	Frt	
	Under 100 TOB	**100 TOB & Over**
MP 4.6. South Alliance, crossover turnouts	25	25
MP 6.9, Letan, crossover turnouts	35	35
MP 12.0, MP 12.0, crossover turnouts	35	35
MP 13.8, Bonner, turnout	35	35
MP 17.3, N Angora, turnout	35	35
MP 21.1, MP 21.1, crossover turnouts	40	40
MP 27.5, MP 27.5, crossover turnouts	45	45
MP 33.7, Northport, crossover turnouts	25	25
MP 33.8, Northport, turnout MT2 - Sterling Main	25	25
MP 34.4, UP Crossing, turnouts	25	25
MP 36.5, Bridgeport, siding turnouts	30	30
MP 38.5, MP 38.5, turnout	30	30
MP 44.2, Mudd Springs, siding turnouts	25	25
MP 56.4, Dalton, siding turnouts	25	25
MP 69.2, Huntsman, siding turnouts	25	25
MP 83.0, Lorenzo, siding turnouts	25	25
MP 90.0, Peetz, siding turnouts	25	25
MP 98.3, Buchanan, siding turnouts	35	35
MP 112.2, N Sterling, turnouts	25	25

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1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

	Frt	
	Under 100 TOB	100 TOB & Over
MP 1.0 to MP 3.2, track 200	20	20
MP 3.2 to MP 4.6, NWD	20	20
MP 3.2 to MP 4.6, SWD, HER	20	20
Sterling, Coal 1 and Coal 2	20	20

2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car

Third Street Alliance to Sterling............ 143 tons, Restriction A

3. Type of Operation

Main Track

MP 0.3 to 0.9	CTC
MP 4.4 to MP 13.7	CTC, 2 MT
MP 13.7 to MP 17.4	CTC
MP 17.4 to MP 33.8	CTC, 2 MT
MP 33.9 to MP 112.3	CTC
MP 112.3 to MP 115.1	RL

Other Tracks Where CTC is in Effect (GCOR/MWOR 10.0)

West lead between EBCS and WBCS Emerson Street
West leg wye between South Wye and Third Street
Tail track between NBCS and SBCS South Wye
South leg wye between West Northport and UP Crossing
UP transfer between NBCS and EBCS UP Crossing

Interlockings

Milepost	Type	Notes
34.4	Manual	Controlling RR: UP

4. Subdivision Specific Rules Information

Safety Overlay Systems in Effect

- Positive Train Control (PTC) MP 0.3 to MP 112.3
- Hi-Rail Limits Compliance System (HLCS)

GCOR/MWOR 6.19, Flag Protection—When flagging is required, distance will be 2.0 miles.

GCOR/MWOR 8.3, Main Track Switches—At Sterling, CO, the normal position of switches does not apply at the following Main Track switches:

- MP 113.75 Main to Coal 1
- MP 113.67 Main to Coal 2
- MP 57.2 UP Main to UP Pass (normal position for this switch is lined into the pass)

These switches may be left lined as last used; however, they must be locked. Trains must approach these switches expecting to find them lined against their movement.

Helping Stalled DP Trains—Stalled distributed power trains that must add helpers to the head end of the train under the direction of the specific subdivision Operating Officer are to operate as outlined below.

ABTH Rules 102.11, 102.11.3, and 102.11.4 are amended only for this move to read:

ABTH 102.11, Helper Operations—When adding helpers to the head end of a DP train, the control of all locomotives coupled together must be transferred to the DP road locomotive engineer by plugging in the MU cable, whenever practicable. When more than one locomotive is attached to a train, the engineer of the DP road locomotive must control the train's air brakes. The engineer in the lead locomotive consist is in charge of train movement. The engineer in charge will communicate with and direct the engineer on the DP road locomotive as follows:

1. Identify speed restrictions and locations where a stop is to be made at least 2 miles in advance.
2. Communicate clearly the name or aspect of signals affecting the train's movement as soon as the signals become visible or audible.

Note: The helper engineer will be responsible to comply with whistle requirements and may utilize the ABV handle, even though cut out, to initiate an emergency application of the brakes should any emergency situation occur requiring this action. The speed limit for a train in this configuration must not exceed 20 MPH.

Helperlink - When utilizing HelperLink equipped locomotives in Helper Service, after coupling to train to be assisted, the Road Engineer on the lead consist of the train will Arm the ETD on the Helper Locomotive with the assistance of the Helper Engineer. Once the ETD is armed, an Emergency Application is required utilizing the Emergency Switch on the Lead Locomotive as outlined in ABTH 102.12.3 and Helper Engineer verifies upon visual inspection that Helper Locomotive Brakes apply. After successful test and air is recovered on Helper Locomotive Consist, train may depart once brake release is verified by visual inspection. Operation of Helpers and Helper Link instructions or this Subdivision are found in the current General Notice.

ABTH 102.11.3, Adding Manned Helper to Head End of Train—When a manned helper is coupled on the head end of the train, the helper engineer will transfer control of the air brakes (and the throttle with MU cable) to the road engineer as follows:

1. Before opening angle cocks between the road locomotive and the manned helper, the engineer on the helper locomotive will:
    a. Communicate with the road engineer to determine the brake pipe reduction currently applied to the train.
    b. The helper engineer must make a reduction 2 psi more than the current reduction applied to the train.
    c. After brake pipe exhaust has ceased, cut out the automatic brake valve and place handle in the release position.
    d. Notify the engineer on the road locomotive of the amount of the brake pipe pressure reduction
    e. The independent brake valve must be left cut in on the helper locomotive. Place the independent brake valve handle in the release position and actuate to fully release the brakes on the helper locomotive consist.
2. The engineer on the road locomotive will:
    a. After opening the angle cocks between the helper and the road locomotive, increase brake pipe reduction to at least 20 psi and helper crew will observe that brakes apply on helper consist by visual inspection.
    b. When train is ready to depart, perform DP train check to check brake pipe continuity as brakes are released as per ABTH Rule 105.4 Also observe by visual inspection that brakes release on helper consist.

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ABTH 102.11.4, Removing Manned Helper from Head End of Train—When a manned helper will be detached from the head end of the train do the following:

1. The engineer in control of the road locomotive will:
   a. Make not less than a 6 psi brake pipe reduction.
   b. Notify the helper engineer when ready to detach the manned helper after closing the angle cocks between the helper consist and the road locomotive and removing the MU cable.
2. The helper engineer will cut in the Automatic Brake Valve after the angle cocks are closed between the consists.
3. After the helper consist is detached, the Engineer on the road locomotive will increase the brake reduction on the train to not less than 15 psi before the train departs.

5. Trackside Warning Devices (TWD)

MP	Device	Recall Code	Notes
Type B. Locations			
4.6	DED		Exception reporting
8.7	DED		Exception reporting
12.0	DED		Exception reporting
16.0		708	Exception reporting
21.0	DED		Exception reporting
25.2	DED		Exception reporting
29.4	DED		Exception reporting
39.4		718	Exception reporting
46.8	DED		Exception reporting
52.5	DED		Exception reporting
57.8	DED		Exception reporting
61.5		717	Exception reporting
66.7	DED		Exception reporting
72.6	DED		Exception reporting
77.5	DED		Exception reporting
82.1	DED		Exception reporting
85.9		728	Exception reporting
104.5		727	Exception reporting

6. FRA Excepted Track—None

7. Special Conditions

Northport—Foreign line movements into UPRR Northport must contact the UPRR Dispatcher to receive instructions affecting movement before occupying UPRR trackage in accordance with GCOR 1.14. If unable to contact the UPRR Dispatcher be governed by BNSF Dispatcher instructions. BNSF crews operating on UPRR trackage at Northport are not required to have a UPRR Timetable or SSI in their possession. All movements over UPRR trackage at Northport by BNSF crews must be made at restricted speed regardless of signal indication unless otherwise restricted.

Trains received from UPRR at Northport have received a proper initial terminal air test by UPRR under run-through certified with the FRA.

When trains are delivered to the UPRR at Northport and are left unattended, hand brakes are to be applied on the 5 head cars and comply with ABTH 102.1.1 and ABTH 106.3. Close all cab doors and windows.

Interchange Trains From UPRR at Northport—Prior to accepting and departing Northport with UPRR trains, the outbound crew must make a safety appliance inspection of all locomotives including remote engines. Any issues qualifying as Federal defects must be reported to the UPRR and the BNSF Fort Worth Mechanical Desk and the crew is to be governed by their instructions.

Buchanan—Crews must contact the Angora Dispatcher before departing Buchanan for yarding instructions.

Excessive Wind Warnings—The first sentence of System Special Instructions, Item 33 is amended to read: When wind warnings in excess of 60 MPH are received, the train dispatcher will notify all trains and employees with movement authority in the area, providing the time and limits of the expected high winds.

SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with Two Switch Machines (Movable Point Frogs/Swing Nose Frogs/Derail):
  - MP 21.1
  - MP 27.5
  - Northport
  - MP 38.5
- ICS in effect:
  - MP 1.0, South Wye, crossover between Sterling Main and Tail Track
  - MP 21.1 *
  - MP 27.5 *
  - Northport *

* Denotes all crossover switches within Control Point are ICS.

Close/No Clearance Locations

Location	Track Name	Track No.	Obstruction
Angora	Back Track	2201	Elevator, buildings
Bridgeport	House Track	2405	Elevator, buildings
	Stateline Bean	2411	Buildings
	Ethanol Plant	2424	Buildings, loading area
Dalton	House Track	2601	Elevator, buildings
	Stub Track	2602	Elevator, buildings
Gurley	Elevator Track	2704	Elevator, fall protection poles
Huntsman	Elevator Track	2801	Elevator, fall protection poles
Sidney	Glover Group Track	2901	Buildings
Lorenzo	Elevator Track	3003	Elevator
Peetz	Elevator Track	3101	Elevator, buildings
MP 104.5	MT		Mechanical monitoring device
MP 112.1	MT		Mechanical monitoring device

Close Track Centers

Location	Track Name	Track No.
Dalton	House Tracks	2601 - 2602

Test Miles

MP 3.0 to MP 4.0
MP 9.0 to MP 10.0
MP 23.0 to MP 24.0
MP 41.0 to MP 42.0
MP 64.0 to MP 65.0
MP 87.0 to MP 88.0
MP 103.0 to MP 104.0

8. Line Segments

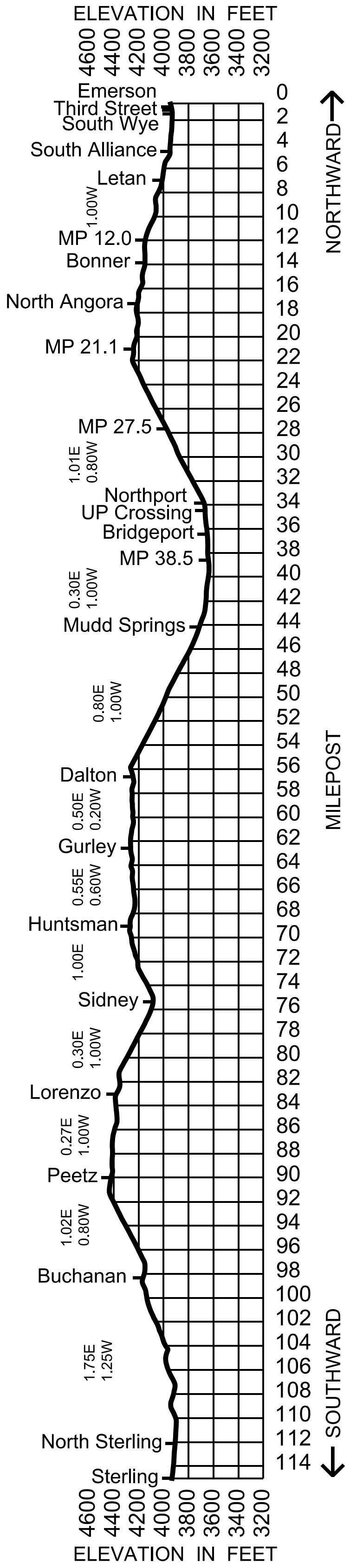
Segment No.	Limits	Milepost
Road Line Segments		
21	Third St to Sterling	MP 0.3 to MP 115.1

TOC Home

9. Other Location Information

Station No.	Name	Mile Post	Capacity in Feet	Switch Opens
32007	Letan Trk 2001 - MT2	6.7	300	North
32014	Bonner Trk 2197 - MT2	13.5	1,250	Both
32022	Angora Trk 2202 - MT1	21.0	2,600	North
32027	Vance Back Trk - 2301 - MT2	27.6	2,500	Both
32034	UP Conn Trks 104 & 105	34.3		Both
84003	Bridgeport Trk 2401	36.3	2,350	Both
84003	Bridgeport Trk 2402	36.3	2,200	Both
84003	Bridgeport Trk 2403	36.3	2,150	Both
84003	Bridgeport Trk 2404	36.3	2,800	Both
84003	Bridgeport Trk 2408	36.6	250	South
84003	Bridgeport Trk 2409	36.8	750	South
84003	Bridgeport Trk 2411	36.9	5,700	North
84023	Dalton Trk 2601	56.5	1,000	Both
84023	Dalton Trk 2602	56.7	1,100	South
84026	Gurley Trk 2701	62.8	2,900	Both
84026	Gurley Trk 2702	62.8	2,400	Both
84026	Gurley Trk 2703	62.8	2,400	Both
84026	Gurley Trk 2704	62.8	650	Both
84035	Huntsman Wye Trk to Sidney and Lowe RR - Trk 2802 & 2803	69.1		North
84042	Sidney Trk 2902	75.7	1,950	Both
84042	Sidney UP Conn Trk - 2905	75.1		South
84042	Sidney Trk 2901	75.7	2,850	Both
84050	Lorenzo Trk 3001	83.4	1,800	Both
	Padroni Trk 3301	103.8	1,750	North
84073	Ginther Trk 3401	106.2	600	South
84078	Ackerman Trk 3501	111.6	1,250	South

10. Grade Chart



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WESTWARD ↓

↑ EASTWARD

Length of Siding (Feet)	Station Nos.	Mile Post	Black Hills Subdivision **MAIN LINE** STATIONS	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.
Adjoining Sub: Butte Subdivision Boundary: Black Hills, MP 476.1 / Butte, MP 476.1							
	30475	476.1	EDGEMONT	B	CTC 2 MT	4	0.6
	30476	476.7	DEADWOOD JCT				2.1
		478.8	MP 478.8	X(2)			5.5
	30483	484.3	MARIETTA		CTC		10.3
	30494	494.6	DEWEY				10.2
		504.8	CROSSOVER 504.8	X(2)	CTC 2 MT		5.2
		510.0	CROSSOVER 510.0	X(2)			6.3
		516.3	CROSSOVER 516.3	X(2)			4.4
	30519	520.7	NEWCASTLE	B			2.6
		523.3	CROSSOVER 523.3	X(2)			5.5
	30527	528.8	PEDRO		CTC		5.3
	30534	534.1	OSAGE				5.6
		539.7	CROSSOVER 539.7	X(2)	CTC 2 MT		7.5
		547.2	CROSSOVER 547.2	X(2)			13.1
		560.3	CROSSOVER 560.3	X(2)			6.7
		567.0	CROSSOVER 567.0	X(2)			7.6
		574.6	MP 574.6	X(2)			6.8
		581.4	ROZET	X(2)			3.0
		584.4	CROSSOVER 584.4	X(2)			2.0
	30587	586.4	EAST DONKEY CREEK Adj. Sub: Orin, MP 586.4	JTX(2)			1.2
	30588	587.6	EAST CAMPBELL Adj. Sub: Campbell, MP 587.5	JTX			0.6
	30588	588.2	WEST CAMPBELL Adj. Sub: Campbell, MP 588.2	JT			1.7
		589.9	MP 589.9		CTC		4.6
		594.5	EAST GILLETTE				2.7
	30596	597.2	GILLETTE	BCPT	CTC 2 MT		0.7
		597.9	CROSSOVER 597.9	X(2)			2.0
		599.9	WEST GILLETTE				123.8
Adjoining Sub: Big Horn Subdivision Boundary: Black Hills, MP 599.9 / Big Horn, MP 599.9							

Mountain Continental Time in effect on Black Hills Subdivision

Radio Call-In		
Radio Channel 039 in service at Edgemont Yard and as Switching Channel for Bullet and Road Crews		
Radio Channel 070 in service at Edgemont Yard for Yard Van		
Radio Channel 085 in service Edgemont to E. Gillette		
Edgemont N - 24(X)	Newcastle - 31(X)	Upton - 32(X)
Moorcroft - 34(X)	Rozet - 35(X)	Donkey Creek - 33(X)
Radio Channel 041 in service at Donkey Creek Yard		
Radio Channel 070 in service Gillette Yard - 45(X)		
Radio Channel 054 in service E. Gillette to W. Gillette		
Oriva - 76(X)		
Emergency - Call 911		
Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3, Railroad Police X=4, Detector Desk X=5		

Dispatcher Information

Edgemont to E. Gillette—817-867-8080 or 817-352-2481,
Fax 817-352-7067
E. Gillette to W. Gillette—817-867-7066, Fax 817-352-7061

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

	Frt	
Main Track	**Under 100 TOB**	**100 TOB & Over**
MP 476.1 to MP 599.9	60	45

Other Tracks Where CTC is in Effect (GCOR/MWOR 10.0)

MP 586.3 to MP 587.5, W Donkey Creek lead	25	25

Temperature Restrictions

Contact the train dispatcher if in doubt of the temperature. Notify the train dispatcher when the train is restricted.

MP 476.1 to MP 599.9, - 10 deg. F & under	45	30

1(B). Speed—Permanent Restrictions

	Frt
MP 476.1 to MP 477.0	35
MP 516.3 to MP 519.6	50
MP 519.6 to MP 521.0	35
MP 521.0 to MP 525.6	50
MP 562.0 to MP 571.5	50
MP 582.2 to MP 586.7	40
MP 595.7 to MP 597.9, MT1, HER	20
MP 596.8 to MP 597.9, MT2, HER	30
MP 599.8 to MP 599.9	45

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

	Frt	
	Under 100 TOB	**100 TOB & Over**
MP 478.8, crossover turnouts	35	35
MP 484.3, Marietta, turnout	40	40
MP 494.6, Dewey, turnout	40	40
MP 504.8, crossover turnouts	25	25
MP 510.0, crossover turnouts	25	25
MP 516.3, crossover turnouts	25	25
MP 523.3, crossover turnouts	25	25
MP 528.8, Pedro, turnout	40	40
MP 534.1, Osage, turnout	40	40
MP 539.7, crossover turnouts	25	25
MP 547.2, crossover turnouts	25	25
MP 560.3, crossover turnouts	50	45
MP 567.0, crossover turnouts	40	40
MP 574.6, crossover turnouts	50	45
MP 581.4, Rozet, crossover turnouts	40	40
MP 584.4, crossover turnouts	25	25
MP 586.4, East Donkey Creek, all dual control turnouts	25	25
MP 587.6, East Campbell, all dual control turnouts	25	25
MP 589.9, turnout	40	40
MP 594.5, E Gillette, turnout	40	40
MP 597.9, crossover turnouts	40	40
MP 599.9, W Gillette, turnout	35	25

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1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

	Frt	
	Under 100 TOB	100 TOB & Over
Donkey Creek yard, except through switches and turnouts	20	20
Rozet to MP 583.8, Svalina crossing, E Lead	20	20
Donkey Creek yard, fuel track	5	5

2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car

Edgemont to Gillette............................ 143 tons, Restriction A

3. Type of Operation

Main Track

MP 476.1 to MP 484.3	CTC, 2 MT
MP 484.3 to MP 494.6	CTC
MP 494.6 to MP 528.8	CTC, 2 MT
MP 528.8 to MP 534.1	CTC
MP 534.1 to MP 589.9	CTC, 2 MT
MP 589.9 to MP 594.5	CTC
MP 594.5 to MP 599.9	CTC, 2 MT

Other Tracks Where CTC is in Effect (GCOR/MWOR 10.0)

Donkey Creek Lead between East Donkey Creek and East Campbell

4. Subdivision Specific Rules Information

Safety Overlay Systems in Effect

- Hi-Rail Limits Compliance System (HLCS)

GCOR/MWOR 6.19, Flag Protection—When flagging is required, distance will be 2.0 miles.

GCOR 5.8.4, Whistle Quiet Zone—Whistle signal 5.8.2(7) is not required at the following crossing locations. All other whistle requirements remain in effect.

Location	Milepost	Crossing Name
Newcastle, WY	520.74**	US 16/Main St.
	521.08**	Walker Ave.
	521.49	Grove Ave.
Moorcroft, WY	569.11	Yellowstone Ave.
Gillette, WY	593.48	Potter Ave.
	594.43	Garner Lake Rd
	596.82	Brooks Ave
	597.97	Burma Ave
	599.53	Foothills Blvd

**Automated Horn System—The AHS is activated by the approaching train which sounds a warning in conjunction with the automatic crossing devices. When the crossing signals are activated the AHS will automatically sound horn at crossing.

To confirm AHS is functioning, an indicator flashes at the crossing. After indicator is observed to be flashing, whistle signal Rule 5.8.2(7) is no longer required.

The train horn must be sounded if the wayside horn indicator is not visible approaching the crossing or if the wayside horn indicator, or an equivalent system, indicates that the system is not operating as intended.

Helping Stalled DP Trains—Stalled distributed power trains that must add helpers to the head end of the train under the direction of the specific subdivision Operating Officer are to operate as outlined below.

ABTH Rules 102.11, 102.11.3, and 102.11.4 are amended only for this move to read:

ABTH 102.11, Helper Operations—When adding helpers to the head end of a DP train, the control of all locomotives coupled together must be transferred to the DP road locomotive engineer by plugging in the MU cable, whenever practicable. When more than one locomotive is attached to a train, the engineer of the DP road locomotive must control the train’s air brakes. The engineer in the lead locomotive consist is in charge of train movement. The engineer in charge will communicate with and direct the engineer on the DP road locomotive as follows:

1. Identify speed restrictions and locations where a stop is to be made at least 2 miles in advance.
2. Communicate clearly the name or aspect of signals affecting the train’s movement as soon as the signals become visible or audible.

Note: The helper engineer will be responsible to comply with whistle requirements and may utilize the ABV handle, even though cut out, to initiate an emergency application of the brakes should any emergency situation occur requiring this action. The speed limit for a train in this configuration must not exceed 20 MPH.

ABTH 102.11.3, Adding Manned Helper to Head End of Train—When a manned helper is coupled on the head end of the train, the helper engineer will transfer control of the air brakes (and the throttle with MU cable) to the road engineer as follows:

1. Before opening angle cocks between the road locomotive and the manned helper, the engineer on the helper locomotive will:
    a. Communicate with the road engineer to determine the brake pipe reduction currently applied to the train.
    b. The helper engineer must make a reduction 2 psi more than the current reduction applied to the train.
    c. After brake pipe exhaust has ceased, cut out the automatic brake valve and place handle in the release position.
    d. Notify the engineer on the road locomotive of the amount of the brake pipe pressure reduction.
    e. The independent brake valve must be left cut in on the helper locomotive. Place the independent brake valve handle in the release position and actuate to fully release the brakes on the helper locomotive consist.
2. The engineer on the road locomotive will:
    a. After opening the angle cocks between the helper and the road locomotive, increase brake pipe reduction to at least 20 psi and helper crew will observe that brakes apply on helper consist by visual inspection.
    b. When train is ready to depart, perform DP train check to check brake pipe continuity as brakes are released as per ABTH Rule 105.4 Also observe by visual inspection that brakes release on helper consist.

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ABTH 102.11.4, Removing Manned Helper from Head End of Train—When a manned helper will be detached from the head end of the train do the following:

1. The engineer in control of the road locomotive will:
   a. Make not less than a 6 psi brake pipe reduction.
   b. Notify the helper engineer when ready to detach the manned helper after closing the angle cocks between the helper consist and the road locomotive and removing the MU cable.
2. The helper engineer will cut in the Automatic Brake Valve after the angle cocks are closed between the consists.
3. After the helper consist is detached, the Engineer on the road locomotive will increase the brake reduction on the train to not less than 15 psi before the train departs.

5. Trackside Warning Devices (TWD)

MP	Device	Recall Code	Notes
Type B. Locations			
480.7	DED		Exception reporting
486.1	DED		Exception reporting
492.0		248	Exception reporting
498.0	DED		Exception reporting
503.0	DED		Exception reporting
508.0	DED		Exception reporting
514.8		318	Exception reporting
519.6	DED		Exception reporting
527.0	DED		Exception reporting
532.7		327	Exception reporting
537.7	DED		Exception reporting
541.7	DED		Exception reporting
545.3	DED		Exception reporting
548.9		328	Exception reporting
554.2	DED		Exception reporting
558.3	DED		Exception reporting
563.8	DED		Exception reporting
568.9	DED		Exception reporting
573.8		338	Exception reporting
578.8	DED		Exception reporting
582.8	DED		Exception reporting
587.6	DED		Exception reporting
591.9	DED		Exception reporting
597.9	DED		Exception reporting, Radio channel 054

6. FRA Excepted Track—None

7. Special Conditions

Edgemont—Trains entering the yard or setting out cars should contact either the Alliance North Dispatcher or the Edgemont Yard Switch Engine (0700 to 1500) for yarding instructions. Crews are responsible for reporting work done at Edgemont. Current instructions for reporting work completed should be utilized.

Crew Changes at Edgemont—Eastward trains should not block the west crossing without a signal at MP 477.2 of at least approach medium. Westward trains will crew change at the east highway crossing unless the train is short enough to clear the east crossing while stopped at the depot.

Deadwood Spur—extends from Deadwood Jct 2.2 miles.

Donkey Creek Yard—Donkey Creek Yard is on the north side of MT1 between Rozet and East Donkey Creek. Switches to Tracks 101 through 109 in Donkey Creek Yard are push-button operated solar switches. Trains parking at Donkey Creek Yard are required to pull up to the crossing holding back 100 feet, or 2 car lengths, but no more than 200 feet or 4 car lengths from any crossing at the end of the track.

Gillette—Contact the crew van using channel 070. Crew vans picking up or dropping off crews between Crossover 597.9 and West Gillette will operate on accessible roads on the north and south sides of the main track. Employees being picked up or delivered in this area are prohibited from walking up or down the embankment on the south side of the main track.

Roll-by Inspections—After changing crews, the relieved crew will be required to give outbound train a roll-by inspection if train will depart within 15 minutes.

Track Side Monitor (TSM) - Coal Dust—Track Side Monitor (TSM) instrumentation designed to actively monitor Coal Dust is located at MP 558.2. The north tower is located 35 feet north of MT1 and the south tower is located 65 feet south of MT2. There is no designed communication between the monitoring station and train crews. All employees of BNSF Railway, or other train engine employees governed by this general order, operating on the Black Hills subdivision will immediately advise the dispatcher if they observe that the coal dust monitor tower (TSM) MP 558.2, Black Hills subdivision appears to have been damaged or otherwise impacted.

Excessive Wind Warnings—The first sentence of System Special Instructions, Item 33 is amended to read: When wind warnings in excess of 60 MPH are received, the train dispatcher will notify all trains and employees with movement authority in the area, providing the time and limits of the expected high winds.

SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with Two Switch Machines (Movable Point Frogs/Swing Nose Frogs/Derail):
  - Marietta
  - MP 547.2 crossover
  - MP 560.3 crossover
  - MP 567.0 crossover
  - MP 574.6 crossover
  - Rozet
  - East Donkey Creek
  - East Campbell

- ICS in effect:
  - MP 478.8 *
  - MP 560.3 *
  - MP 567.0 *
  - MP 574.6 *
  - Rozet *
  - MP 584.4 *
  - East Donkey Creek *
  - East Campbell *

* Denotes all crossover switches within Control Point are ICS.

Close/No Clearance Locations

Location	Track Name	Track No.	Obstruction
Donkey Creek	Rip track	301	Light Pool East End
Gillette	Reynolds Pipe	1009	Building
	East City Track	1021	Building
	Elevator Track	1022	Building

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Close Track Centers

Location	Track Name	Track Nos.
Gillette	Yard	1004 - 1006

Test Miles

MP 486.0 to MP 487.0
MP 497.0 to MP 502.0
MP 578.0 to MP 579.0

Flash Flood Critical Areas

MP 497.0 to MP 502.0

8. Line Segments

Segment No.	Limits	Milepost
Road Line Segments		
4	Edgemont to W Gillette	
181	Deadwood Spur	
Yard Line Segments		
892	Edgemont	
897	Newcastle	
911	Donkey Creek	
952	Gillette	

9. Other Location Information

Stn No.	Name	Mile Post	Capacity in Feet	Switch Opens
30483	Marietta Back Trk 701 - MT1	484.2	450	East
30494	Dewey Back Trk 801 - MT1	495.6	750	Both
30494	Dewey Back Trk 802 - MT2	495.6	750	Both
	508.0 Back Trk 9801 - MT1	508.1	1,000	Both
	508.0 Back Trk 9802 - MT2	508.1	1,000	Both
30527	Pedro Back Trk 9601 - MT1	527.6	1,000	Both
30527	Pedro Back Trk 9602 - MT2	527.6	1,000	Both
30534	Osage Chip Trk 9401 - MT1	535.4	1,000	Both
	539.8 Back Trk 9411 - MT1	539.8	1,050	Both
	539.8 Back Trk 9412 - MT2	539.8	1,050	Both
30541	Jerome 9311 - MT2	543.3	2,250	West
	547.5 Back Trk 9201 - MT1	547.5	500	Both
30548	Upton Industrial Park Trk 9205 - MT2	548.7	2,400	Both
30548	Upton Storage Trk 9204 - MT2	549.0	7,800	Both
30555	Black Hills Bentonite Trk 9001 - MT2	556.1	1,900	Both
30555	Black Hills Bentonite Trk 9002 - MT2	555.9	450	Both
30555	557.0 Back Trk 9011 - MT1	557.0	1,500	Both
30555	557.0 Back Trk 9012 - MT2	557.0	1,500	Both
30568	Moorcroft Cement Plant Trk (Stock Trk) 8801	568.6	5,500	Both
30568	Moorcroft BTI (Back Trk) 8802	568.6	1,000	East
30568	Moorcroft Back Trk 8811 - MT1	5686	1,250	Both
30568	Moorcroft Back Trk 8812 - MT2	568.6	1,250	Both
30581	Rozet Fertilizer Trk 8709 - MT2	581.8	750	East
30581	Rozet No 3 Trk 8703 - MT2	583.0	7,900	Both
30581	Rozet No 4 Trk 8704 - MT2	583.0	7,900	Both
30581	Rozet Pocket Trk 8702	584.4	1,500	Both
30587	Donkey Creek No 3 Trk 1503 - MT2	585.0	8,200	Both
30587	Donkey Creek No 4 Trk 1504 - MT2	585.0	8,200	Both
30587	Donkey Creek 236 Stub - MT2	586.2	2,000	West
30587	Donkey Creek 237 Stub - MT2	586.2	2,000	West
	Minturn 8505	590.4	2,500	Both
30589	W. Wyodak 8502	591.7	200	West
30596	Gillette Cab Trk 1019 - MT2	597.2	250	Both

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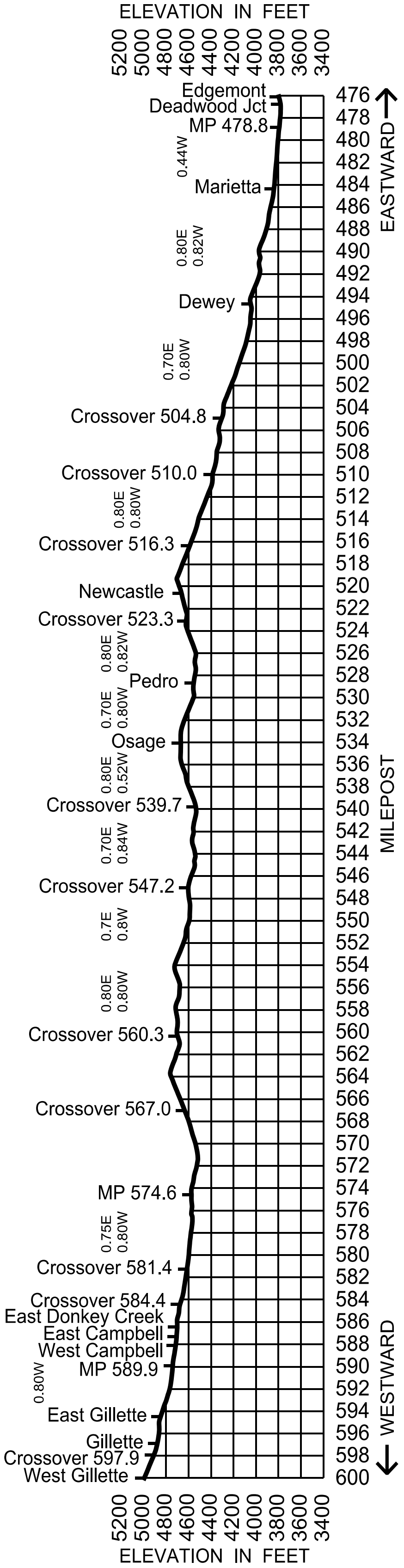
10. Grade Chart



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WESTWARD ↓

Length of Siding (Feet)	Station Nos.	Mile Post	Butte Subdivision MAIN LINE STATIONS	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.
	30364	365.6	ALLIANCE	BT		4	0.3
End Butte Sub MT, MP 365.9; Connection with Sand Hills Sub MT, MP 364.1, 1.8 miles East of End MT via GCOR/MWOR 6.28							
		365.9	EMERSON Adj. Sub: Angora. MP 365.9	JX(2)	CTC		0.3
		366.2	THIRD STREET Adj. Sub: Angora, MP 366.2	JX			2.5
		368.7	MP 368.7		CTC 2 MT		0.5
		369.2	WEST ALLIANCE				7.0
	30374	376.2	BEREA		CTC		9.0
	30383	384.6	HEMINGFORD				2.2
		386.8	CROSSOVER 386.8	X			5.4
		392.2	CROSSOVER 392.2	X(2)			8.3
		400.5	MP 400.5	X(2)			7.9
		408.4	CROSSOVER 408.4	X			1.3
10,227	30409	409.7	BELMONT	X			10.1
		419.8	CROSSOVER 419.8	X(2)	CTC 2 MT	4	3.2
	30422	423.0	CRAWFORD	BX			0.6
		423.6	MP 423.6	X			1.9
		425.5	MP 425.5	X			10.1
		435.6	MP 435.6	X(2)			9.6
		445.1	CROSSOVER 445.1	X(2)			6.1
	30449	451.2	ARDMORE				7.6
14,167	30457	458.8	RUMFORD		CTC		6.4
	30466	465.2	PROVO				7.0
		472.2	MP 472.2	X(2)	CTC 2 MT		3.0
		475.2	EAST EDGEMONT				0.9
	30475	476.1	EDGEMONT	BT			110.9
Adjoining Sub: Black Hills Subdivision Boundary: Butte, MP 476.1 / Black Hills, MP 476.1 Information for Edgemont is located in the Black Hills Sub Timetable							

↑ EASTWARD

Mountain Continental Time in effect on Butte Subdivision

Radio Call-In

Radio Channel 070 in service at Alliance Yard

Radio Channel 087 in service:
Westward: W. Alliance to Edgemont
Eastward: Edgemont to Berea

Alliance West - 20(X)	Belmont - 21(X)	Crawford - 25(X)

Edgemont W - 24(X)

Radio Channel 063 in service Hemingford to Crawford for Switching

Emergency - Call 911

Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3, Railroad Police X=4, Detector Desk X=5, PTC Desk X=9

Alliance Terminal Radio Channels

Channel 049 in service for switching operations in South Yard. The repeater switching channel for programmable radios is 015-049.

Channel 059 in service inside designated Mechanical Limits.

Channel 070 all radio transmissions between inbound/outbound trains and the Yardmaster or Diesel Tower, except in an emergency situation or as directed by the Yardmaster.

Channel 078 in service for switching operations in North Yard. The repeater switching channel for programmable radios is 075-009.

Channel 096 in service for taxi and crew vans.

Dispatcher Information
817-867-7078, Fax 817-352-7057

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

	Frt	
Main Track	**Under 100 TOB**	**100 TOB & Over**
MP 365.9 to MP 476.1	60	45

Temperature Restrictions
Contact the train dispatcher if in doubt of the temperature. Notify the train dispatcher when the train is restricted.

MP 365.9 to MP 476.1, - 10 degrees F & under	45	30

1(B). Speed—Permanent Restrictions

	Frt
MP 365.9 to MP 366.2	10
MP 393.6 to MP 400.4	40
MP 408.4 to MP 412.8	30
MP 412.8 to MP 414.1	20
MP 414.1 to MP 418.8	25
MP 418.8 to MP 423.6	40
MP 438.6 to MP 446.0	50
MP 466.7 to MP 474.8	45
MP 474.8 to MP 476.1	35

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

	Frt	
	Under 100 TOB	**100 TOB & Over**
MP 368.7, turnouts	25	25
MP 369.2, West Alliance, crossover turnouts	25	25
MP 376.2, Berea	35	35
MP 384.6, Hemingford	35	35
MP 386.8, crossover turnouts	25	25
MP 392.2, crossover turnouts	25	25
MP 400.5, crossover turnouts	50	45
MP 408.4, turnout to siding	15	15
MP 408.4, crossover turnouts	25	25
MP 409.7, Belmont, turnout to siding	15	15
MP 409.7, Belmont, crossover turnouts	25	25
MP 419.8, crossover turnouts	25	25
MP 423.0, Crawford, all turnouts	25	25
MP 423.6, crossover turnouts	25	25
MP 425.5, crossover turnouts	40	40
MP 435.6, crossover turnouts	50	45
MP 445.1, crossover turnouts	40	40
MP 451.2, Ardmore	40	40
MP 458.8, Rumford, siding turnouts	35	35
MP 465.2, Provo	50	45
MP 472.2, crossover turnouts	35	35

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1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

	Frt	
	Under 100 TOB	100 TOB & Over
Light engines all tracks in Alliance Terminal outside Mechanical department limits, not including switches and turnouts	20	20
Tracks 100, 101 and 102 from Emerson (MP 365.9) to E. Alliance (MP 364.0) including turnouts and 102/103 switch	20	20
Old East Alliance hand throw crossover from Track 101 to Track 102 including turnouts	20	20
Engine Servicing Tracks Old Trinidad Bean Spur (Track 310)	5	5
Bean Spur Tracks 1 through 4 (Tracks 131-134)	5	5
Casey 1 and Casey 2 (Tracks 286 and 287)	5	5
Alliance, Switch Engine Spur at 30 Shanty (Track 285)	5	5
Alliance, South Engine Tie-Up Track at 59 Shanty (Track 227)	5	5
Alliance, South Storage Track at 59 Shanty (Track 235)	5	5
Alliance, Track 114 and 116	5	5
Crawford Track 2	5	5

2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car

East Alliance to Edgemont .... 143 tons, Restriction C

Location	Track Name	Track No.
Six-axle locomotives exceeding 186 tons are not permitted west of west derail on:		
	Old Trinidad Bean Track	310
Locomotives are not permitted west of CMR boxcar on:		
	Middle City Track	312

3. Type of Operation

Main Track

MP 365.9 to MP 366.2	CTC
MP 366.2 to MP 376.2	CTC, 2 MT
MP 376.2 to MP 384.6	CTC
MP 384.6 to MP 451.2	CTC, 2 MT
MP 451.2 to MP 465.2	CTC
MP 465.2 to MP 476.1	CTC, 2 MT

4. Subdivision Specific Rules Information

Safety Overlay Systems in Effect:

- Positive Train Control (PTC) MP 365.8 to MP 384.7
- Hi-Rail Limits Compliance System (HLCS)

GCOR/MWOR 6.19, Flag Protection—When flagging is required, distance will be 2.0 miles.

GCOR/MWOR 8.20, Derail Location and Position—Crossover MP 425.5—Derails on MT1 and MT2 Crawford Helper Pocket—tracks will be left locked in “non-derailing” position except when engines or cars are left unattended on those tracks.

Helping Stalled DP Trains—Stalled distributed power trains that must add helpers to the head end of the train under the direction of the specific subdivision Operating Officer are to operate as outlined below.

ABTH Rules 102.11, 102.11.3, and 102.11.4 are amended only for this move to read:

ABTH 102.11, Helper Operations—When adding helpers to the head end of a DP train, the control of all locomotives coupled together must be transferred to the DP road locomotive engineer by plugging in the MU cable, whenever practicable. When more than one locomotive is attached to a train, the engineer of the DP road locomotive must control the train’s air brakes. The engineer in the lead locomotive consist is in charge of train movement. The engineer in charge will communicate with and direct the engineer on the DP road locomotive as follows:

1. Identify speed restrictions and locations where a stop is to be made at least 2 miles in advance.
2. Communicate clearly the name or aspect of signals affecting the train’s movement as soon as the signals become visible or audible.

Note: The helper engineer will be responsible to comply with whistle requirements and may utilize the ABV handle, even though cut out, to initiate an emergency application of the brakes should any emergency situation occur requiring this action. The speed limit for a train in this configuration must not exceed 20 MPH.

Helperlink - When utilizing HelperLink equipped locomotives in Helper Service, after coupling to train to be assisted, the Road Engineer on the lead consist of the train will Arm the ETD on the Helper Locomotive with the assistance of the Helper Engineer. Once the ETD is armed, an Emergency Application is required utilizing the Emergency Switch on the Lead Locomotive as outlined in ABTH 102.12.3 and Helper Engineer verifies upon visual inspection that Helper Locomotive Brakes apply. After successful test and air is recovered on Helper Locomotive Consist, train may depart once brake release is verified by visual inspection. Operation of Helpers and Helper Link instructions or this Subdivision are found in the current General Notice.

ABTH 102.11.3, Adding Manned Helper to Head End of Train—When a manned helper is coupled on the head end of the train, the helper engineer will transfer control of the air brakes (and the throttle with MU cable) to the road engineer as follows:

1. Before opening angle cocks between the road locomotive and the manned helper, the engineer on the helper locomotive will:
   a. Communicate with the road engineer to determine the brake pipe reduction currently applied to the train.
   b. The helper engineer must make a reduction 2 psi more than the current reduction applied to the train.
   c. After brake pipe exhaust has ceased, cut out the automatic brake valve and place handle in the release position.
   d. Notify the engineer on the road locomotive of the amount of the brake pipe pressure reduction
   e. The independent brake valve must be left cut in on the helper locomotive. Place the independent brake valve handle in the release position and actuate to fully release the brakes on the helper locomotive consist.

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2. The engineer on the road locomotive will:
    a. After opening the angle cocks between the helper and the road locomotive, increase brake pipe reduction to at least 20 psi and helper crew will observe that brakes apply on helper consist by visual inspection.
    b. When train is ready to depart, perform DP train check to check brake pipe continuity as brakes are released as per ABTH Rule 105.4 Also observe by visual inspection that brakes release on helper consist.

ABTH 102.11.4, Removing Manned Helper from Head End of Train—When a manned helper will be detached from the head end of the train do the following:

1. The engineer in control of the road locomotive will:
    a. Make not less than a 6 psi brake pipe reduction.
    b. Notify the helper engineer when ready to detach the manned helper after closing the angle cocks between the helper consist and the road locomotive and removing the MU cable.
2. The helper engineer will cut in the Automatic Brake Valve after the angle cocks are closed between the consists.
3. After the helper consist is detached, the Engineer on the road locomotive will increase the brake reduction on the train to not less than 15 psi before the train departs.

5. Trackside Warning Devices (TWD)

MP	Device	Recall Code	Notes
Type B. Locations			
367.9	DED		Exception reporting
374.4	DED		Exception reporting
379.6	DED		Exception reporting
386.8	DED		Exception reporting
390.4		208	Exception reporting
394.0	DED		Exception reporting
401.0	DED		Exception reporting, MT2
406.2		218	Exception reporting
412.7	DED		Exception reporting
414.2	DED		Exception reporting
417.6	DED		Exception reporting
422.4	DED		Exception reporting
428.2		258	Exception reporting
433.0	DED		Exception reporting
439.5	DED		Exception reporting
443.0	DED		Exception reporting
449.1	DED		Exception reporting
454.4		238	Exception reporting
459.5	DED		Exception reporting
463.8	DED		Exception reporting
468.6		308	Exception reporting

6. FRA Excepted Track—None

7. Special Conditions

Alliance Terminal Instructions

Prior to occupying switching leads, or fouling adjacent tracks, permission must be obtained from the yardmaster.

Trains Departing Alliance on Butte Subdivision—The following stretch brake method will be used for all trains departing Alliance Yard onto the Butte Subdivision from either leg of the wye.

DP Trains:
While operating in independent control (screen split), ensure power and proper direction of travel of remote unit as prescribed by 2nd paragraph of ABTH Rule 105.9. Once both are verified, return remote unit to idle and depart using head end power only until entire train is clear of Third Street.

All Trains:
Except when an emergency exists, if required to stop before the entire train is clear of the wye, use the following procedure to control slack action:

1. If in a throttle position higher than 3, reduce throttle to 3 or below.
2. Make a minimum brake pipe reduction and ACTUATE.
3. After the initial brake pipe reduction and the train slack has adjusted, throttle must be gradually reduced to IDLE position.
4. The independent brake must not be allowed to apply while still in power.
5. As the train comes to a stop, make a final brake pipe reduction and allow the locomotive brakes to apply.

All trains setting out bad order cars using the Wye, whether North Yard or South Yard, must not kick cars. All cars must be shoved to the set out track and the above instructions for stopping their train apply.

Alliance Diesel Pit Instructions—Contact the Diesel Pit Foreman on radio channel 059 (or 070 if 059 not available) before arrival at the Pit (including 400’s, 600’s, Departure Track, and 160 track) and ascertain if power is ready to move and be governed by Foreman’s instructions before boarding and moving equipment. When operating locomotives within these areas use radio channel 059 if available.

Alliance Designated Mechanical Limits—The following designated limits are under the exclusive control of the Mechanical Department:

Diesel Pit and Diesel Shop:
- Trackage East of North gate derail and blue light
- Trackage West of Steel Track derail and blue light
- Trackage West of East gate derail and blue light
- Trackage East of Departure Track derail and blue light
- Trackage East of West Diesel Shop Derail and blue light

Car Shop:
- Trackage West of East Car Shop, 500 Lead Switch and blue light
- Trackage East of West Car Shop 503, 504, 505, 506, and 507 Switch and blue light

Blue Light:
- The Blue Light located on the West End between tracks 506 and 507 will govern movements on track 506.
- The Blue Light located on the West End between tracks 507 and 500 lead will govern movement on track 507.
- The Blue Light located approximately 120 feet west of the 500 Lead Track Switch between the South Runaround and the 500 Lead Track governs movement into the 500 tracks.

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Heating Plant:

- Trackage East of West Heating Plant Switch and blue light

South Yard:

- Trackage between the derails on track 761
- South Pump 513
- North Pump 514
- South Engine Tie Up 227
- South Engine Storage 235

Radio Communication at Diesel Pit and Shop Areas—All inbound engines coming into the Mechanical Facility using East Gate, West Gate, or Steel Track must use the telephones located at the Blue Light when communicating with the Diesel Tower Foreman for an inbound track. When entering the Mechanical Facility via the departure track, crew must contact the Diesel Tower by radio on channel 059 (160.975).

Inbound coal trains, upon leaving Berea, will contact North Yardmaster to allow timely communication to the Mechanical Dept. for positioning of required train inspections.

Jelinek Spur—Cars must not occupy east 300 feet of Jelinek Spur without track bulletin protecting close clearance on MT1 Track. To spot Co-op industry, the Jelinek electric lock must be used. When spotting cars on the Jelinek Spur, all cars must be walked in or out. Riding cars is not permitted account no clearance. Train line air must be cut into cars handled on this track.

Watch out for close clearance between MT1 and Jelinek Spur at Third Street, MP 366.2. There is no room for employees to ride equipment account track centers at this location are 13 feet.

Berea—Cars must not occupy west 500 feet of elevator track without track bulletin protecting close clearance on main one.

Belmont—Cars left on the storage track must be left east of the back track so track machines can be moved.

Excessive Wind Warnings—The first sentence of System Special Instructions, Item 33 is amended to read: When wind warnings in excess of 60 MPH are received, the train dispatcher will notify all trains and employees with movement authority in the area, providing the time and limits of the expected high winds.

SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with two Switch Machines (Movable Point Frogs/Swing Nose Frogs/Derail):
  - MP 368.7 Switches are equipped with split point derails
  - MP 400.5
  - MP 408.4 Belmont
  - Crawford between No. 2 track switch and MT1, MP 423.1. Targer will display red only when lined for MT1.
  - MP 423.6
  - MP 425.5
  - MP 435.6
  - MP 458.8 E Rumford
  - MP 461.0 W Rumford
  - MP 472.2
- ICS in effect:
  - MP 400.5 *
  - MP 423.6
  - MP 425.5
  - MP 435.6 *
  - MP 472.2 *

* Denotes all crossover switches within control point are ICS.

Close/No Clearance Locations

Location	Track Name	Track No.	Obstruction
Alliance Yard	Conoco Bldg MP 366.3	100	Building
	Old Bean Track	310	Building
	Westco	314	Building
	Jelinek Spur	315	Building
	Kelly Bean	316	Shed/poles
	New Alliance Bean	317	Building
	East Dock	508	Dock
	Wrecker Track	510	Building
	Coal Plant	511	Building
	T310	512	Building
	South Pump	513	Rig platform
	North Pump	514	Rig platform
	South Oil Dock	516	Dock
Crawford	MP 422.2	MT1	Bridge pillar
Hemingford	Stock Track	1404	Building
Berea	Elevator Track	1201	Elevator

Close Track Centers

Location	Track Name	Track Nos.
Alliance	Yard	126-127
Alliance Diesel		606-607, 9948-9949, 9952-9953, 9968
Crawford	Yard	1802-1803

Test Mile

MP 366.3 to MP 367.3
MP 371.0 to MP 372.0
MP 389.0 to MP 390.0
MP 433.0 to MP 434.0
MP 461.0 to MP 462.0

8. Line Segments

Segment No.	Limits	Milepost
Road Line Segments		
4	E Alliance to Edgemont	
Yard Line Segments		
890	Alliance	
891	Alliance Shop	

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WESTWARD ↓

↑ EASTWARD

Length of Siding (Feet)	Station Nos.	Mile Post	Canyon Subdivision **MAIN LINE** **STATIONS**	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.
Adjoining Sub: Valley Subdivision Boundary: Canyon, MP 90.4 / Valley, MP 90.4							
		90.4	EAST GUERNSEY	R	RL	5	4.6
	32129	95.0	GUERNSEY	BRT	RL 2 MT		0.6
		95.6	WEST GUERNSEY	R	RL		0.4
		96.0	MP 96.0		CTC		1.7
		97.7	EAST STOKES		CTC 2 MT		3.1
		100.8	WEST STOKES		CTC		2.5
4,667	32137	103.3	WENDOVER Adj. Sub: Front Range, MP 103.4	JT			4.5
		107.8	EAST CASSA		CTC 2 MT		3.2
	32145	111.0	CASSA				0.7
		111.7	WEST CASSA		CTC		6.8
	32152	118.5	EAST ELKHORN		CTC 2 MT		4.3
		122.8	WEST ELKHORN		CTC		5.6
		128.4	MP 128.4		CTC 2 MT		2.9
		131.3	CROSSOVER 131.3	X(2)			1.9
		133.2	BRIDGER JCT	JT			42.8
Adjoining Subs: Casper & Orin Subdivision Boundary: Canyon, MP 133.2 / Casper, MP 133.2 / Orin, MP 127.3							

Mountain Continental Time in effect on Canyon Subdivision

Radio Call-In	
Radio Channel 045 in service at Guernsey Yard	
Radio Channel 066 in service E. Guernsey to Bridger Jct.	
Wendover - 84(X)	Bona - 85(X)
Emergency - Call 911	
Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3, Railroad Police X=4, Detector Desk X=5	

Dispatcher Information
817-867-8076 or 817-352-6180, Fax 817-352-6260

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

	Frt	
Main Track	**Under 100 TOB**	**100 TOB & Over**
MP 90.4 to MP 95.6	30	30
MP 95.6to MP 133.2	50	45

Temperature Restrictions
Contact the train dispatcher if in doubt of the temperature. Notify the train dispatcher when the train is restricted.

MP 95.6 to MP 133.2, - 10 degrees F & under	45	30

1(B). Speed—Permanent Restrictions

	Frt
MP 93.5 to MP 93.7, MT1 and MT2 through fuel platform area until entire movement clears the area	10
MP 95.6 to MP 101.7	25
MP 101.7 to MP 115.0	35
MP 107.8 to MP 111.7, MT2	25
MP 125.2 to MP 127.5	35

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

	Frt	
	Under 100 TOB	**100 TOB & Over**
MP 95.6, W Guernsey, turnout	25	25
MP 97.7, E Stokes, turnout	25	25
MP 100.8, W Stokes, turnout	25	25
MP 102.3, E Wendover, turnout	25	25
MP 103.4, W Wendover, turnout	25	25
MP 107.8, E Cassa, turnout	25	25
MP 111.7, W Cassa, turnout	25	25
MP 118.5, E Elkhorn, turnout	25	25
MP 122.8, W Elkhorn, turnout	25	25
MP 128.4, turnout	40	25
MP 131.3, crossover turnouts	50	40

1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

Guernsey Yard (Between MP 90.4 and MP 95.6), lite engine consists operating on other than main tracks (excluding switches, turnouts and within Mechanical Limits)	20	20
Empty WWD unit trains between MP 90.4 and MP 91.2, on East Yard Lead, Guernsey Yard	20	20

2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car

Guernsey to Wendover .... 143 tons, Restriction B
Wendover to Bridger Jct. .... 143 tons, Restriction A

3. Type of Operation

Main Track

MP 90.4 to MP 93.9	RL
MP 93.9 to MP 95.4	RL, 2 MT
MP 95.4 to MP 95.6	RL
MP 95.6 to MP 97.7	CTC
MP 97.7 to MP 100.8	CTC, 2 MT
MP 100.8 to MP 107.8	CTC
MP 107.8 to MP 111.7	CTC, 2 MT
MP 111.7 to MP 118.5	CTC
MP 118.5 to MP 122.8	CTC, 2 MT
MP 122.8 to MP 128.4	CTC
MP 128.4 to MP 133.2	CTC, 2 MT

4. Subdivision Specific Rules Information

Safety Overlay Systems in Effect:

- Hi-Rail Limits Compliance System (HLCS)

GCOR 5.8.4, Whistle Quiet Zone—Whistle signal 5.8.2(7) is not required at the following crossing locations. All other whistle requirements remain in effect.

Location	Milepost	Crossing Name
Glendo, WY	119.64	A Street / WO 319 Connector
	119.92	5th Street

GCOR/MWOR 6.19, Flag Protection—When flagging is required, distance will be 2.0 miles.

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GCOR 6.21.3, Track Obstruction / Unusual Condition—When a train is advised in the words, “Between (location) and (location) be governed by Rule 6.21.3”, within specified limits, train must not exceed 20 MPH, watching out for slide, rock, washout or debris on track.

Train crews are reminded to regulate speed where visibility is limited (ex. curvature of track, weather, etc.)

GCOR/MWOR 8.3, Main Track Switches—the following switches may be left locked in the position last used:
MP 95.45—Track 201
MP 95.4—MT1 and MT2 West End
MP 94.1—West Crossover MT1 to track 201
MP 93.7—East Crossover MT1 to the Lead
MP 93.6—MT1 and MT2 East End
MP 91.8—Crossover from the MT to 281 track
MP 91.2—Crossover from the MT to the east yard Lead

Trains, engines and on-track equipment must approach these switches expecting to find them lined against their movement.

5. Trackside Warning Devices (TWD)

MP	Device	Recall Code	Notes
Type A. Locations Protecting Bridges, Tunnels or Other Structures			
112.1		198	
Type B. Locations			
112.1		198	
116.6	DED		Exception reporting
120.6	DED		Exception reporting
126.3		687	Exception reporting
129.8	DED		Exception reporting

6. FRA Excepted Track—None

7. Special Conditions

Guernsey—Road crews are required to communicate with the Guernsey Yardmaster on channel 045 for instructions when entering, departing, or moving within Guernsey Yard. Yard switch crews will operate on channels 021 and 059 as designated by the Guernsey Yardmaster. Channel 016 is in effect at the Guernsey Diesel Facility. All movements entering, departing, or within the Diesel Facility must communicate with the Diesel Shop Foreman on channel 016. Yard Carmen will communicate on channel 074.

Wendover—The main track, siding, east and west legs of wye, tracks 405, 406, 497, 498 and 499 within restricted limits at Wendover are under the jurisdiction of the Front Range Dispatcher. All other tracks, excluding the CTC Main Track within the confines of Wendover are under the jurisdiction of the Guernsey Yardmaster.

Crews must report all set out and pickups at Wendover utilizing VTR.

Double Stack and Boeing Cars—Trains handling double stack cars and Boeing cars will not exceed 10 MPH at the following locations while operating through tunnels No. 1 and No. 3.
Between MP 96.5 and MP 97.5
Between MP 101.1 and MP 101.6

Excessive Wind Warnings—The first sentence of System Special Instructions, Item 33 is amended to read: When wind warnings in excess of 60 MPH are received, the train dispatcher will notify all trains and employees with movement authority in the area, providing the time and limits of the expected high winds.

SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with two Switch Machines (Movable Point Frogs/Swing Nose Frogs/Derail):
  - MP 128.4
  - MP 131.3 crossover
- ICS in effect:
  - MP 131.3 *

* Denotes all crossover switches within control point are ICS.

Test Mile
MP 120.0 to MP 121.0

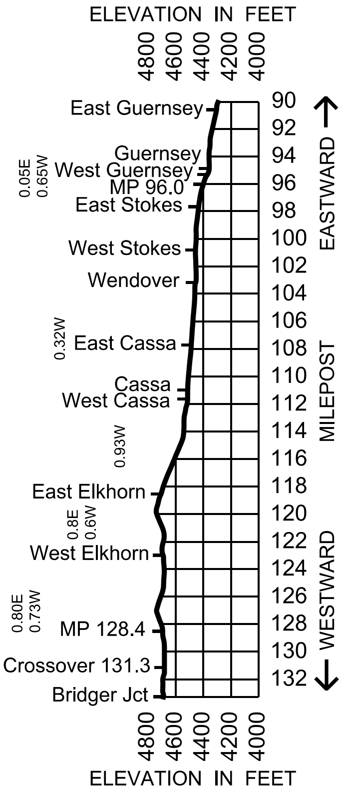
8. Line Segments

Segment No.	Limits	Milepost
Road Line Segments		
5	E Guernsey to Bridger Jct	MP 90.4 to MP 133.2
Yard Line Segments		
893	Guernsey	
Ballast Pit		
899	Guernsey	

9. Other Location Information

Station No.	Name	Mile Post	Capacity in Feet	Switch Opens
32145	Cassa Setout Trk 597	111.6	1,400	East
32153	Glendo Setout Trk 690	119.6	800	West
32152	Elkhorn Setout Trk 697	119.9	900	West

10. Grade Chart



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WESTWARD ↓	Length of Siding (Feet)	Station Nos.	Mile Post	Ravenna Subdivision **MAIN LINE** **STATIONS**	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.	↑ EASTWARD
				Adjoining Sub: Creston, Heartland Division Subdivision Boundary: Ravenna, MP 7.0 / Creston, MP 7.0X					
			11.0	CP 110	X(2)	CTC 2 MT	4	13.4	
			24.4	CP 244	X(2)			MT1-3.4 MT2-8.0	
			27.8	BR JCT (Main 1) Adj. Sub: Bellwood, MP 27.7	J			1.1	
			28.9	CP 289 (Main 1) Adj. Sub: Bellwood, MP 28.9	J			4.4	
			33.3	CP 333	X(2)			6.7	
			40.0	CP 400	X(2)			10.5	
			50.5	CP 505	X(2)			5.4	
		30055	55.9	YORK	P			4.4	
			60.3	CP 603	X(2)			18.2	
			78.5	CP 785	BJPT			4.8	
		30082	83.3	MURPHY	X(2)			11.1	
			94.4	CP 944 (Main 1)				0.5	
			94.9	GRAND ISLAND		CTC		2.7	
			97.6	MCDONALD		CTC 2 MT		12.0	
			109.6	CP 1096	X(2)			15.5	
			125.1	NANTASKET	X(2)			2.6	
		30126	127.7	RAVENNA	CPTX			0.5	
		30128	128.2	WEST RAVENNA				117.2	
				Adjoining Sub: Sand Hills Subdivision Boundary: Ravenna, MP 128.2 / Sand Hills, MP 128.2					

Central Continental Time in effect on Ravenna Subdivision

Radio Call-In		
Radio Channel 039 in service CP 61 to West Ravenna		
Pleasant Dale - 05(X)	York - 01(X)	Aurora - 02(X)
Cairo - 03(X)	Ravenna E - 04(X)	
Radio Channel 066 in service Aurora Yard		
Emergency – 911		
Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3, Railroad Police X=4, Detector Desk X=5, PTC Desk X=9		

Dispatcher Information
817-867-7083, Fax 817-352-7072

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

	Psgr	Frt	
Main Track		Under 100 TOB	100 TOB & Over
MP 7.0 to MP 128.2	60	60	50

Temperature Restrictions
Contact the dispatcher if in doubt of the temperature.
Notify the dispatcher when the train is restricted.

MP 7.0 to MP 14.6, MT2 MP 20.6 to MP 29.2, MT, MT2 MP 36.6 to MP 44.8, MT2 MP 56.2 to MP 66.6, MT2 MP 87.7 to MP 92.1, MT1, MT2 MP 99.2 to MP 118.6, MT2 MP 118.6 to MP 125.1	95 degrees & over	60	50	40

1(B). Speed—Permanent Restrictions

MP 53.6 to MP 56.2	45	45	45

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

MP 11.0, CP 110, crossover turnout	40	40	25
MP 24.4, CP 244, crossover turnouts	40	40	40
MP 28.9, CP 289, turnout	25	25	25
MP 33.3, CP 333, crossover turnouts	50	50	50
MP 40.0, CP 400, crossover turnouts	40	40	40
MP 50.5, CP 505, crossover turnouts	50	50	50
MP 60.3, CP 603, crossover turnouts	40	40	40
MP 68.4, CP 684, crossover turnouts	50	50	50
MP 77.2, CP 772, turnout	20	20	20
MP 77.9, CP 779, crossover turnouts	50	50	50
MP 77.9, CP 779, turnout to East Wye Giltner Sub	25	25	25
MP 78.5, CP 785, crossover turnouts	50	50	50
MP 78.5, CP 785, turnout between MT2 and W Wye Giltner	25	25	25
MP 79.2, CP 792, turnout between MT1 and Aurora yard lead	30	30	30
MP 79.2, CP 792, turnout between MT1 and Aventine track	10	10	10
MP 83.3, Murphy, crossover turnouts	40	40	40
MP 94.9, Grand Island, turnout	50	50	50
MP 97.6, McDonald, turnout	50	50	50
MP 109.6, CP 1096, crossover turnouts	50	50	50
MP 125.1, Nantasket, crossover turnouts	40	40	40

1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

Bradshaw, over scale on Elevator Tracks	5	5	5
Aurora, East Lead track 2300, HER	20	20	20
Aurora, East Lead track 2300	30	30	30
Aurora, West Lead track 2320, HER	20	20	20
Aurora, West Lead track 2320	30	30	30

2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car
MP 6.3 to West Ravenna...................... 143 tons, Restriction A
York to Benedict on Benedict Spur....... 143 tons, Restriction D

3. Type of Operation

Main Track

MP 7.0 to MP 94.9	CTC, 2 MT
MP 94.9 to MP 97.6	CTC
MP 97.6 to MP 128.2	CTC, 2 MT

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4. Subdivision Specific Rules Information

Safety Overlay Systems in Effect

- Hi-Rail Limits Compliance System (HLCS)
- Positive Train Control (PTC), MP 7.0 to MP 99.1

GCOR 2.12, Approach Signal Announcement—IIn signaled territory and operating on a road radio channel, when a train is passing a signal displaying either an approach indication or a diverging approach indication in advance of a control point a crew member must transmit the following by radio:

- Train identification - initials, engine number, and direction
- Signal name
- Next control point location or milepost of signal
- Track - (on single track, MT designation is not necessary)
- Speed

Example: BNSF 4196 East, Approach in advance of MP 82.8, 29 MPH.

GCOR 5.8.4, Whistle Quiet Zone—Whistle signal 5.8.2(7) is not required at the following crossing locations. All other whistle requirements remain in effect.

Location	Milepost	Crossing Name
Aurora, NE	78.26	1st Street

GCOR 6.19—When flagging is required, distance will be 2.0 miles.

5. Trackside Warning Devices (TWD)

See System Special Instructions for additional Trackside Warning Device (TWD) information

MP	Device	Recall Code	Notes
Type B. Locations			
10.9	DED		Exception reporting
16.3		057	
22.7	DED		Exception reporting
26.8	DED		Exception reporting
34.0		056	
40.1	DED		Exception reporting
45.0	DED		Exception reporting
49.1	DED		Exception reporting
52.6		028	Exception reporting
58.6	DED		Exception reporting
62.7	DED		Exception reporting
67.8	DED		Exception reporting
74.0		028	
80.1	DED		Exception reporting
85.4	DED		Exception reporting
90.3		038	
97.9	DED		Exception reporting
102.7	DED		Exception reporting
107.3		048	
111.8	DED		Exception reporting
116.6	DED		Exception reporting
121.8	DED		Exception reporting
Type C. Locations			
74.5	WILD	748	

6. FRA Excepted Track

Palmer Lead, Bonavilla stub track switch to north end of lead.

7. Special Conditions

Waco—Push button lights equipped with a 60 minute timer are located at Waco to assist TYE crews with switching movements. The push buttons are located at the east end of the MT1 and MT2 set out track.

Benedict Spur—extends from York 9.5 miles.

Bradshaw, Bonnevilla Industry Track—Trains must not occupy the Road G Crossing until the crossing warning lights warning automobile traffic have been operating for at least 20 seconds or until the movement is protected by a crew member.

Aurora—Trains or engines operating on other than the main track must not occupy crossings at MP 77.6, 9th street, and MP 78.2, 1st street, until the crossing lights warning automobile traffic have been operating for at least 20 seconds or the movement is protected by a crew member. “Crossing Signal Start” signs are located 75 feet East and West of 2nd street and 9th street crossings on all tracks other than the Main Track. The crossing lights will activate when the movement passes the “Crossing Signal Start” signs.

Palmer Lead—extends from Aurora 9.5 miles.

CoPlant—Trains must not occupy the Highway 2 crossing until the crossing lights warning automobile traffic have been operating for at least 20 seconds or until the movement is protected by a crew member.

Ravenna—When trains and/or lite locomotive consists are located between MP 127.7, Highway 68 Overpass, and MP 127.2, the east switch at Cargill, trains and/or lite locomotive consists are not required to sound GCOR whistle signal 5.8.2(3) prior to departing Ravenna.

West Ravenna—The absolute signals at West Ravenna are controlled by the Sand Hills Subdivision, Alliance East Dispatcher on Channel 066.

Distributed Power, Independent Mode—For better control of drawbar forces, manifest trains (H & M Symbols) and Loaded bulk commodity trains (G, C & U Symbols) equipped with distributed power equipment must be operated utilizing Independent Mode and as outlined in ABTH Rule 105.10 Distributed Power Train Handling, between the following milepost locations:
MP 43 to MP 58
MP 86 to MP 100
MP 111 to MP 116

Independent Mode may also be utilized at any other location not specified above at the discretion of the Locomotive Engineer.

SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with Two Switch Machines (Moveable Point Frogs/Swing Nose Frogs/Derail):
  - MP 33.3 CP 333, MT1 and MT2
  - MP 68.4 CP 684, MT1 and MT2
  - MP 77.2 CP 772
  - MP 77.9 CP 779, MT1 and MT2
  - MP 78.5 CP 785, MT1 and MT2
  - MP 79.2 CP 792
  - MP 94.9 Grand Island
  - MP 97.6 McDonald
- ICS—in effect
  - MP 33.3 CP 333
  - MP 60.3 CP 603 *
  - MP 68.4 CP 684 *
  - MP 77.9 CP 779 *
  - MP 78.5 CP 785 *

* Denotes all crossover switches within control point are ICS.

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Close/No Clearance Locations

Location	Track Name	Track No.	Obstruction
Emerald	Elevator Spur	1602	Elevator
Pleasant Dale	Farmers COOP	1701	Elevator
Milford	Elevator Track	2502	Elevator
Tamora	Elevator Track	1302	Elevator
Utica	Elevator Track	1501 - 1502	Elevator
Waco	E Elevator Track	1411	Elevator
York	High Plains COOP	1901	Elevator
		1902	Building
		1903	Gates
	Nebr. Energy	1931	Gates
Benedict Line	Industry Track	1997	Building
	Cement Plant	1951	Cement plant
	Kroy Ind.	1961	Benedict Spur
	Statex Stub Trk.	1923	Building
Bradshaw	York Mfg.	2101	Gates
	Track 1	2111	Building
Beigert Bros.	Center Track	2103	Loading pipe
	North Track	2102	Loading pipe
Hampton	Elevator Track	2211	Building
	S Fertilizer Trk.	2201	Building
	Center Fertz Trk.	2202	Building
	N Fertilizer Trk.	2203	Building
MP 74.5	MT		Mechanical Monitoring Device
Aurora	Hoard Track	2310	Building
Aurora COOP Elevator	Short E Stub	2331	Building
	Short W Stub	2332	Building
	Connecting Trk.	2333	Building
Nebraska Energy, LLC	Track 1	2601	Building
	Track 2	2602	Building
	Track 3	2603	Building
Palmer Lead	Industry Spur	2321	Gates/building
Curry	Farmland	2401	Building
Monsanto	CHS Inc	2501	Gates
IAMS	Industry Track	2502	Building
		2505 - 2506	Building
Murphy	W Elevator Trk.	2611	Building
	Elevator Trk.	2601	Tanks
	W Stub Track	2612	Building
	E Stub Track	2602	Building
	Anhydrous Stub	2603	Tanks
Phillips	Stub Track	2701	Building
Grand Island	Ag Services	3041	Building
	Millards	3030	Building
	Monfort Trk. 32	3011	Building
	Monfort Trk. 33	3012	Building
	Luzenac Lead	3001	Building
	Luzenac Trk. 1	3021	Building
	Luzenac Trk. 2	3022	Building
Cairo	Setout Track	3601	Building
Nantasket Abengoa Bioenergy	W Lead	3830	Building
	E Lead	3831	Building
	S Crossover	3833A	Building
Ravenna	S Waycar Track	3809	Building
	Roundhouse Trk.	3810	Building
	Cargil Track	3823	Building
	Stock Track	3824	Building

Close Track Centers

Location	Track Name	Track Nos.
Waco	Elevator Tracks	1401 - 1402
York	High Plains	9979 - 1901
	Benedict Line	1977 - 9917
Aurora	W Wye	2317 - 2315
	Industry Spur	2321 - Palmer Spur
CoPlant	Passing Track	Tracks 3289 - MT2

Test Miles

MP 28 to MP 29
MP 69 to MP 70
MP 107 to MP 108
MP 118 to MP 119
MP 126 to MP 127

Flash Flood Critical Areas

MP 14.6 to MP 20.3
MP 117.0 to MP 119.0

8. Line Segments

Segment No.	Limits	Mile Posts
Road Line Segments		
4	MP 7.0 to Ravenna	
148	Benedict Spur	
149	Palmer Lead	

9. Other Location Information

Name		Mile Post	Capacity in Feet	Switch Opens
30008	Emerald MT2	7.8	627	East
30008	Emerald MT1	8.3	590	West
	Seward Setout MT1	29.0	550	East
	Seward Setout MT2	29.5	600	East
	Tamora Setout MT2	29.6	650	West
30041	Utica MT1	42.5	1,050	Both
	Ficke Siding MT1	47.3	2,790	Both
30047	Waco MT1	47.5	1,382	Both
	Waco Setout MT1	49.9	1,100	Both
	Waco Setout MT2	49.9	1,100	Both
	High Plains MT1	53.0	1,823	Both
	Statex 1 MT1	54.8	738	West
	York Setout MT1	55.8	1,040	Both
83209	Benedict	55.9	9,000	East
	OLB Railroad/Farmland	56.9	6,500	Both
	Bonavilla MT1	62.3	450	West
30063	Bradshaw MT1	62.5	9,500	Both
	Beigert Brothers	66.8	785	East
	Nebraska Energy MT1	79.9	9,000	Both
30080	Curry MT1	80.7	940	East
30081	IAMS MT2	83.1	2,250	Both
30088	Phillips	88.9	600	East
30092	Trail	93.6	4,000	Both
	Montfort	94.5	1,260	East
30095	Grand Island	98.2	1,110	West
30103	CoPlant MT2	103.8	2.980	Both
30104	Abbott MT1	104.3	2,250	Both
30104	Abbott MT2	104.5	450	East
30110	Cairo MT1	111.4	980	Both
30110	Cairo MT2	111.4	350	West
30118	St. Michael MT1	118.8	3,020	Both
30118	St. Michael MT2	119.1	1,025	Both
	Abengoa Energy MT2	125.3	9,500	Both

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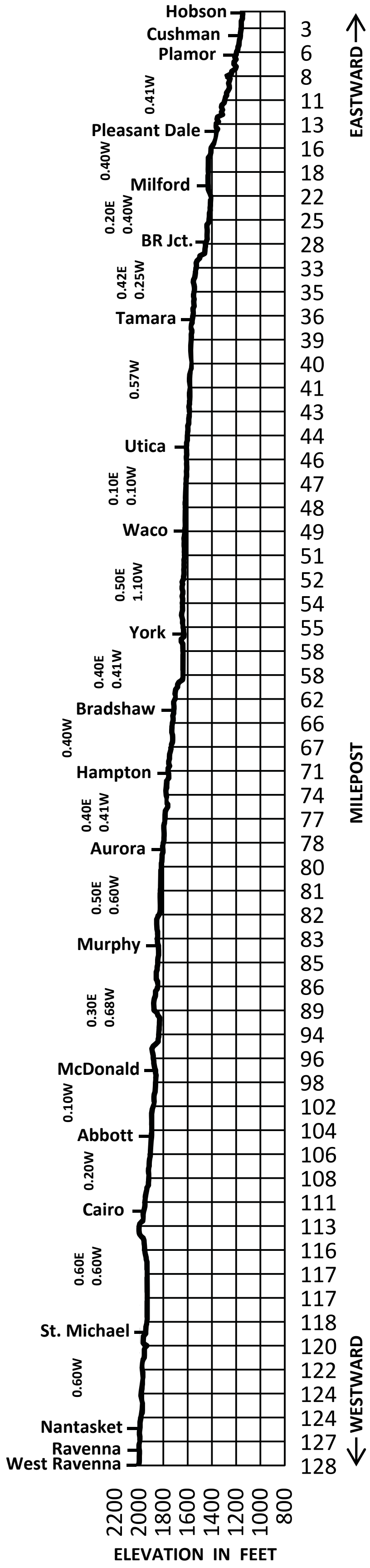
10. Grade Chart



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WESTWARD ↓	Length of Siding (Feet)	Station Nos.	Mile Post	Sand Hills Subdivision MAIN LINE STATIONS	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.	↑ EASTWARD
	Adjoining Sub: Ravenna Subdivision Boundary: Sand Hills, MP 128.2 / Ravenna, MP 128.2								
			128.2	WEST RAVENNA		CTC 2 MT	4	9.6	
		30137	137.8	HAZARD				0.5	
			138.3	CROSSOVER 138.3	X(2)			6.0	
		30143	144.3	LITCHFIELD				0.3	
			144.6	CROSSOVER 144.6	X			6.0	
			150.6	CROSSOVER 150.6	X(2)			4.4	
		30152	155.0	MASON				7.1	
			162.1	CROSSOVER 162.1	X(2)			7.7	
			169.8	CROSSOVER 169.8	X(2)			6.5	
		30175	176.3	BROKEN BOW	B			10.2	
			186.5	CROSSOVER 186.5	X(2)			7.3-MT1 9.7-MT2	
			193.8	MP 193.8 (MT1)				2.3	
			196.1	MP 196.1	X(2)			7.1	
			204.2	MP 204.2	X(2)			5.8	
		30214	214.4	DUNNING		CTC		9.5	
		30224	223.9	HALSEY		CTC 2 MT		6.0	
			229.9	CROSSOVER 229.9	X(2)			7.4	
			237.3	CROSSOVER 237.3	X(2)			9.7	
			247.0	CROSSOVER 247.0	X(2)			7.2	
			254.2	CROSSOVER 254.2	X(2)			9.4	
			263.6	CROSSOVER 263.6	X(2)			10.3	
			273.9	CROSSOVER 273.9	X(2)			9.9	
			283.8	CROSSOVER 283.8	X(2)			7.3	
			291.1	CROSSOVER 291.1	X(2)			9.0	
			300.1	CROSSOVER 300.1	X(2)			6.8	
		30305	306.9	HYANNIS		CTC		7.6	
		30314	314.5	ASHBY		CTC 2 MT		5.7	
			320.2	COVER	X(2)			10.0	
			330.2	MP 330.2	X(2)			3.7	
	8,737	30333	333.9	ELLSWORTH				5.5	
			339.4	CROSSOVER 339.4	X(2)			4.6	
		30341	344.0	LAKESIDE		CTC		5.2	
		30349	349.2	ANTIOCH		CTC 2 MT		8.1	
			357.3	MP 357.3	X(2)			4.5	
			361.8	CROSSOVER 361.8	X(2)			2.2	
			364.0	EAST ALLIANCE	X(2)			236.3	
	End Sand Hills Sub MT, MP 364.1; Connects with Butte Sub GCOR/MWOR 6.28 track at Sand Hills Sub MP 364.1 Information for Alliance Terminal is located in the Butte Sub Timetable								

Central Continental Time in effect on Sand Hills Subdivision

Radio Call-In		
Radio Channel 066 in service West Ravenna to MP 356.6		
Ravenna W - 04(X)	Mason - 13(X)	Broken Bow - 12(X)
Dunning - 14(X)	Seneca - 15(X)	Whitman - 16(X)
Bingham - 17(X)	Lakeside - 18(X)	Alliance East - 10(X)
Radio Channel 070 in service Alliance Yard MP 356.6		
Emergency - Call 911		
Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3, Railroad Police X=4, Detector Desk X=5		

Dispatcher Information

817-867-8077 or 817-352-2473, Fax 817-352-7058

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

	Frt	
Main Track	**Under 100 TOB**	**100 TOB & Over**
MP 128.2 to MP 364.1	60	50

1(B). Speed—Permanent Restrictions—None

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

MP 138.3, crossover turnouts	40	40
MP 144.6, crossover turnouts	25	25
MP 150.6, crossover turnouts	25	25
MP 162.1, crossover turnouts	50	50
MP 169.8, crossover turnouts	25	25
MP 186.5, crossover turnouts	40	40
MP 196.1, crossover turnouts	50	50
MP 204.2, crossover turnouts	50	50
MP 214.5, Dunning, turnout	50	50
MP 223.9, Halsey, turnout	40	40
MP 229.9, crossover turnouts	25	25
MP 237.3, crossover turnouts	40	40
MP 247.0, crossover turnouts	40	40
MP 254.2, crossover turnouts	25	25
MP 263.6, crossover turnouts	50	50
MP 273.9, crossover turnouts	25	25
MP 283.8, crossover turnouts	50	50
MP 291.1, crossover turnouts	50	50
MP 300.1, crossover turnouts	25	25
MP 306.9, Hyannis, turnout	40	40
MP 314.5, Ashby, turnout	40	40
MP 320.2, Cover, crossover turnouts	25	25
MP 330.2, crossover turnouts	50	50
MP 333.9, Ellsworth, siding turnouts	20	20
MP 339.4, crossover turnouts	25	25
MP 344.0, Lakeside, turnout	50	50
MP 349.2, Antioch, turnout	40	40
MP 357.3, crossover turnouts	50	50
MP 361.8, crossover turnouts	40	40
MP 364.0, East Alliance, crossover turnouts	25	25

1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

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2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car

West Ravenna to East Alliance .... 143 tons, Restriction A

3. Type of Operation

Main Track

MP 128.2 to MP 214.4	CTC, 2 MT
MP 214.4 to MP 223.9	CTC
MP 223.9 to MP 306.9	CTC, 2 MT
MP 306.9 to MP 314.5	CTC
MP 314.5 to MP 344.0	CTC, 2 MT
MP 344.0 to MP 349.2	CTC
MP 349.2 to MP 364.1	CTC, 2 MT

4. Subdivision Specific Rules Information

Safety Overlay Systems In Effect

- Hi-Rail Limits Compliance System (HLCS)

GCOR 5.8.4, Whistle Quiet Zone—Whistle signal 5.8.2(7) is not required at the following crossing locations. All other whistle requirements remain in effect.

Location	Milepost	Crossing Name
Broken Bow	175.59	1st Avenue
	175.84	5th Avenue
	176.09**	9th Avenue
	176.15**	10th Avenue

**Crossings with Wayside Horn Installations:

The Wayside Horn System/Automated Horn System (WHS/AHS) is activated by the approaching train which sounds a warning in conjunction with the automatic crossing devices. When the crossing signals are activated the WHS/AHS will automatically sound horn at crossing.

To confirm WSH/AHS is functioning, an indicator flashes at the crossing. After indicator is observed to be flashing, whistle signal Rule 5.8.2 (7) is no longer required

The train horn must be sounded if the wayside horn indicator is not visible approaching the crossing or if the wayside horn indicator, or an equivalent system, indicates that the system is not operating as intended.

GCOR/MWOR 6.19, Flag Location—When flagging is required, distance will be 2.0 miles.

5. Trackside Warning Devices (TWD)

MP	Device	Recall Code	Notes
Type B.Locations			
133.2	DED		Exception reporting
138.3	DED		Exception reporting
141.4		048	Exception reporting
146.7	DED		Exception reporting
150.6	DED		Exception reporting
158.1		138	Exception reporting
164.5	DED		Exception reporting
168.1	DED		Exception reporting
173.3	DED		Exception reporting
178.4	DED		Exception reporting
180.9		128	Exception reporting
184.9	DED		Exception reporting
190.1	DED		Exception reporting
195.9	DED		Exception reporting
200.5		147	Exception reporting
206.0	DED		Exception reporting
210.0	DED		Exception reporting
216.3	DED		Exception reporting
221.1		148	Exception reporting
225.9	DED		Exception reporting
229.9	DED		Exception reporting
235.3	DED		Exception reporting
241.1	DED		Exception reporting
248.9		157	Exception reporting
252.4	DED		Exception reporting
256.5	DED		Exception reporting
261.3		158	Exception reporting
265.6	DED		Exception reporting
269.5	DED		Exception reporting
275.5	DED		Exception reporting
280.5	DED		Exception reporting
286.6		167	Exception reporting
292.8	DED		Exception reporting
295.1	DED		Exception reporting
300.1	DED		Exception reporting
304.5	DED		Exception reporting
309.0		168	Exception reporting
314.5	DED		Exception reporting
320.1	DED		Exception reporting
324.2	DED		Exception reporting
328.3		177	Exception reporting
332.9	DED		Exception reporting
338.1		188	Exception reporting
344.0	DED		Exception reporting
349.2	DED		Exception reporting
354.7	DED		Exception reporting
359.1	DED		Exception reporting
362.8	DED		Exception reporting, Channel 070

6. FRA Excepted Track—None

7. Special Conditions

Cooks Crossing, MP 166.1—The 250 foot markings for cutting this crossing have been moved to 400 feet due to poor visibility. Do not foul these marks when cutting or standing at this crossing.

Anderson Grain Facility, MP 193.8—Split point derail with dispatcher controlled machine is in place on the lead inside the facility.

Hyannis—All trains stopping for meets at Hyannis or parking with the power on at Hyannis must stop back of the back track switch at MP 306.35.

Ellsworth—Eastward trains stopping at Ellsworth, between the hours of 2200 and 0600, must stop back of the eastward whistle marker at MP 334.52.

Excessive Wind Warnings—The first sentence of System Special Instructions, Item 33 is amended to read: When wind warnings in excess of 60 MPH are received, the train dispatcher will notify all trains and employees with movement authority in the area, providing the time and limits of the expected high winds.

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SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with Two Switch Machines (Movable Point Frogs/Swing Nose Frogs/Derail):
  - MP 162.1—Crossover
  - MP 193.8
  - MP 196.1
  - MP 204.2
  - MP 263.6
  - Antioch
  - MP 330.2
  - MP 357.3
- ICS—in effect:
  - MP 162.1 *
  - MP 196.1 *
  - MP 204.2 *
  - MP 263.6 *
  - MP 330.2 *
  - MP 357.3 *

* Denotes all crossover switches within Control Point are ICS.

Close/No Clearance Locations

Location	Track Name	Track No.	Obstruction
Hyannis	Ranch Supply	5801	Building WE
Halsey	Grain Facility	5001	Building WE
Dunning	Grain Facility	4901	Fence WE
Anselmo	Ranch Supply	4701	Building S side
	Grain Facility	4713	Beam/Chute
Merna	Ranch Supply	4602	Building S side
Berwyn	Grain Facility	4420	Building N side WE
MP 349.1	Main track		Mechanical monitoring device

Test Miles

MP 129 to MP 130
MP 141 to MP 142
MP 199 to MP 200
MP 247 to MP 248
MP 272 to MP 273
MP 356 to MP 357
MP 363 to MP 364

8. Line Segments

Segment No.	Limits	Milepost
Road Line Segments		
4	W Ravenna to E Alliance	MP 128.2 to MP 364.0

9. Other Location Information

Station No.	Name	Mile Post	Capacity in Feet	Switch Opens
30132	Sweetwater - 3901 - MT1	133.2	550	West
30137	Hazard Back Trk - 4001 - MT1	137.9	1,500	West
30143	Litchfield Elevator Trk - 4101 - MT1	144.2	1,500	Both
30143	Litchfield Stub Trk #1 - 4102 - MT1	144.2	700	West
30143	Litchfield Stub Trk #2 - 4103 - MT1	144.2	700	West
30143	Litchfield Stub Trk #3 - 4104 - MT1	144.2	750	West
30143	Litchfield Stub Trk #4 - 4105 - MT1	144.2	750	West
30152	Mason Back Trk - 4202 - MT1	155.2	1,670	Both
30152	Mason Back Trk - 4201 - MT2	153.5	400	East
30166	Berwyn Back Trk - 4501 - MT2	159.4	1,480	Both
30159	Ansley - 4340 - MT2	159.5	1,670	Both
30166	Old Berwyn - 4420 - MT1	167.4	1,400	Both
30175	Broken Bow Sargent Pipe - 4506 - MT1	175.3	250	East
30175	Broken Bow Elevator - 4502 - MT1	176.3	500	Both
30175	Broken Bow Mill Trk - 4503 - MT1	176.3	350	West
30175	Broken Bow City Trk - 4504 - MT2	176.0	750	Both
30175	Broken Bow House Trk - 4505 - MT2	176.5	400	West
30183	Merna Elevator Trk - 4602 - MT2	184.3	1,000	Both
30183	Merna Old Pass - 4601 - MT2	184.3	4,500	Both
30183	Back Trk - 4697 - MT1	184.1	1,050	Both
30194	Anselmo Back Trk - 4701 - MT2	195.5	2,000	Both
30194	Anselmo Back Trk - 4797 - MT1	202.1	4,000	Both
30194	Anselmo Back Trk - 4796 - MT2	202.1	4,000	Both
30214	Old Dunning - 4901	215.7	750	West
30224	Halsey Back Trk - 5001 - MT2	225.1	1,250	Both
30234	Natick Back Trk - 5101 - MT2	234.9	1,000	Both
30234	Natick Back Trk - 5102 - MT1	234.9	1,000	Both
30241	Thedford Back Trk - 5202 - MT1	242.2	1,400	Both
30241	Thedford Back Trk - 5201 - MT2	242.2	3,300	Both
30241	Thedford - 5203 - MT2	242.2	350	East
30257	Seneca East Old Pass - 5401 - MT1	256.8	2,800	East
30257	Seneca East #1 Stub Trk - 5403 - MT1	257.1	1,000	East
30257	Seneca West #1 Stub Trk - 5404 - MT1	257.9	1,800	West
30257	Seneca West Old Pass - 5402 - MT1	258.2	3,250	West
30267	Mullen East Stub Trk - 5501 - MT1	268.1	2,000	East
30267	Mullen West Stub Trk - 5502 - MT1	268.8	400	West
30266	Mullen Back Track - 5503 - MT2	266.4	3,000	Both
30277	Hecla Back Trk - 5601 - MT2	278.7	500	Both
30283	Hooker Back Trk - 5650 - MT2	284.1	1,050	Both
30283	Hooker Back Trk - 5651 - MT1	284.1	1,050	Both
30291	Coyote Back Trk - 5750 - MT2	290.2	1,050	Both
30291	Coyote Back Trk - 5751 - MT1	290.2	1,050	Both
30292	Whitman Back Trk - 5701 - MT2	293.7	1,000	Both
30305	Hyannis Back Trk - 5801 - MT2	306.5	1,750	Both
30314	Ashby Back Trk - 5901 - MT2	315.6	750	Both
30323	Bingham Back Trk - 6001 - MT2	323.8	600	Both
30323	Bingham Back Trk - 6096 - MT1	324.2	1,250	Both
30333	Ellsworth Back Trk - 6196 - MT2	332.5	3,200	Both
30333	Ellsworth Back Trk - 6101 - SDG	334.2	600	East
30341	Lakeside Back Trk - 6201 - MT2	341.8	600	Both
30349	Antioch Back Trk - 6301 - MT2	350.4	300	Both
30360	Progress Rail Trks - 831, 832, 833 - MT1	361.8	9,450	Both
30361	AEP Trks - 821, 822, 823 - MT2	361.8	Loop	West
	Koester's Trk - 137 - MT1	363.4	2,100	Both

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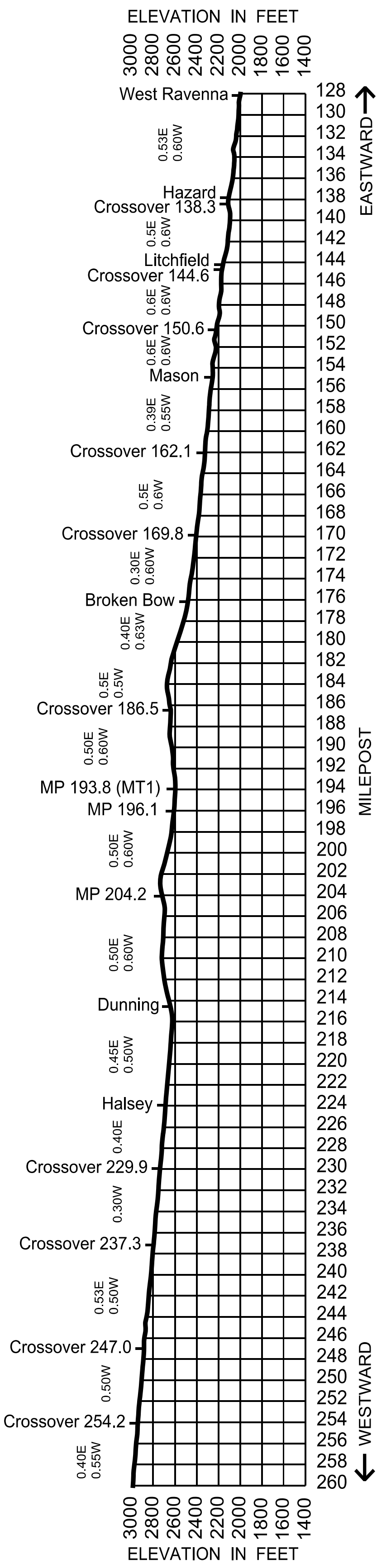
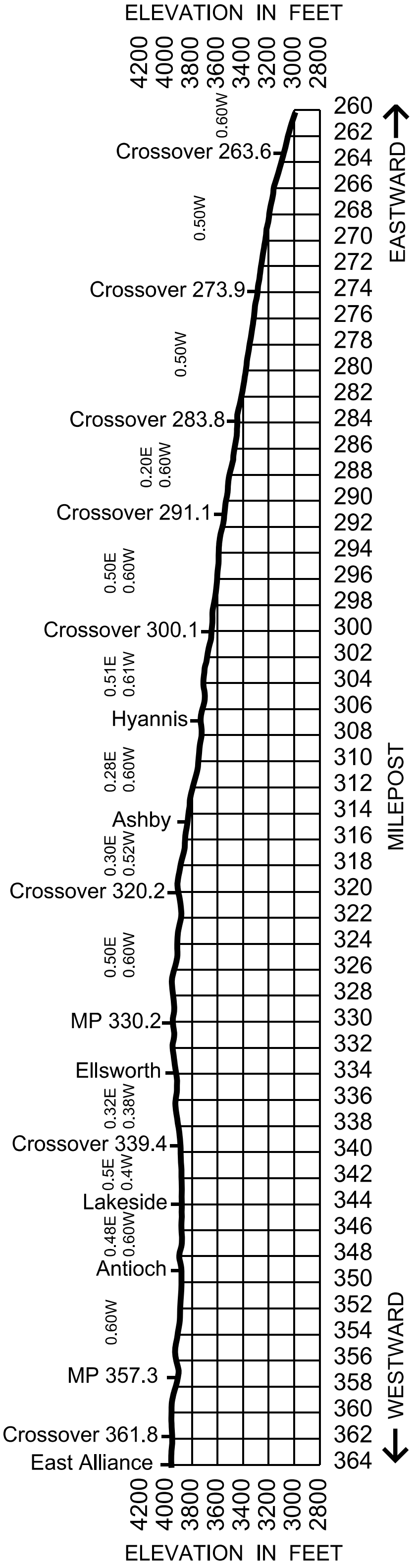
10. Grade Charts





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WESTWARD ↓

↑ EASTWARD

Length of Siding (Feet)	Station Nos.	Mile Post	Valley Subdivision **MAIN LINE** STATIONS	Rule 4.3	Type of Oper.	Line Segment	Miles to Next Stn.
Adjoining Sub: Angora Subdivision Boundary: Valley, MP 0.0 / Angora, MP 33.8 Information for Northport is located in the Angora Sub Timetable							
	32034	0.0	NORTHPORT	JTX	CTC 2 MT	5	0.4
		0.4	WEST NORTHPORT Adj. Sub: Angora, MP 0.4	JTX(2)			2.0
		2.4	MP 2.4 Adj. RR: UP, MP 2.3	JX			4.3
		6.7	MP 6.7	X(2)			3.2
		9.9	ATKINS		CTC		1.9
	32046	11.8	BAYARD				4.1
10,146	32050	15.9	BRADLEY				5.9
	32056	21.8	MINATARE				2.9
9,781	32059	24.7	WINTERS				6.1
	32065	30.8	SCOTTSBLUFF	T			6.0
9,149	32072	36.8	JANE				3.4
	32074	40.2	MITCHELL	T			3.6
	32078	43.8	ENTERPRISE		CTC 2 MT		2.7
	32080	46.5	MORRILL				7.2
	32088	53.7	HENRY				5.4
	32092	59.1	STUART		CTC		3.1
	32096	62.2	TORRINGTON				7.4
9,260	32103	69.6	TEXAS				2.1
	32106	71.7	LINGLE				8.3
10,595	32114	80.0	GRATTAN				2.0
	32116	82.0	FORT LARAMIE				3.5
		85.5	MP 85.5		CTC 2 MT		2.8
		88.3	CROSSOVER 88.3	X(2)			2.1
		90.4	EAST GUERNSEY	R			91.2
Adjoining Sub: Canyon Subdivision Boundary: Valley, MP 90.4 / Canyon, MP 90.4 Information for Guernsey is located in the Canyon Sub Timetable							

Mountain Continental Time in effect on Valley Subdivision

Radio Call-In		
UP DS - Northport - Channel 020 - Call-in *51		
Radio Channel 040 in service at Northport for Switching		
Radio Channel 054 in service Northport to WSS Bradley		
Bridgeport - 71(X)		
Radio Channel 051 in service Minatare to Torrington for Switching		
Radio Channel 077 in service WSS Bradley to E. Guernsey		
Bridgeport - 80(X)	Scottsbluff - 81(X)	Torrington - 82(X)
Guernsey - 83(X)		
Channel 045 in service Guernsey Yard		
Emergency - Call 911		
Dispatcher X=0, Mechanical Desk X=2, Customer Support X=3, Railroad Police X=4, Detector Desk X=5, PTC Desk X=9		

Dispatcher Information

Northport to E. Guernsey - 817-867-7079, Fax 817-352-7060

1. Speed Regulations

See Item 1 of the System Special Instructions for additional speed restrictions.

1(A). Speed—Maximum

Main Track	Frt Under 100 TOB	Frt 100 TOB & Over
MP 0.0 to MP 90.4	50	45

Temperature Restrictions

Contact the train dispatcher if in doubt of the temperature. Notify the train dispatcher when the train is restricted.

MP 0.0 to MP 90.4, - 10 degrees & under	45	30

1(B). Speed—Permanent Restrictions

	Frt
MP 0.0 to MP 0.6	25

1(C). Speed—Sidings and Main Track Switches and Turnouts

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines using sidings must not exceed the siding turnout speed unless otherwise indicated.

	Frt Under 100 TOB	Frt 100 TOB & Over
MP 0.4, West Northport, crossover turnouts and turnout to Angora S leg wye	35	25
MP 2.4, crossover turnouts and turnout to UPRR	50	40
MP 6.7, crossover turnouts	50	45
MP 9.9, Atkins, turnout	50	45
MP 15.9, Bradley, siding turnouts	40	40
MP 24.7, Winters, siding turnouts	35	35
MP 36.8, Jane, siding turnouts	40	40
MP 43.8, Enterprise, turnout	50	45
MP 59.1, Stuart, turnout	50	45
MP 69.6, Texas, siding turnouts	35	35
MP 80.0, Grattan, siding turnouts	35	25
MP 82.2, CP 822, turnout	30	25
MP 83.5, CP 835, turnout	30	25
MP 85.5, turnout	40	25
MP 88.3, crossover turnouts	40	25

1(D). Speed—Other

Trains and engines must not exceed 10 MPH through turnouts unless otherwise indicated. Trains and engines must not exceed 10 MPH on other than main track (GCOR 6.28) unless otherwise indicated.

2. Bridge and Equipment Weight Restrictions

Maximum Gross Weight of Car

Northport to E. Guernsey .... 143 tons, Restriction A

Location	Track Name	Track No.
Six-axle locomotives and six-axle derricks in excess of 165 tons & not more than one locomotive is permitted on:		
Bayard	All Sugar Factory Tracks except Storage 1 & 2	
Mitchell	All Sugar Factory Tracks	
Morrill	Stock, House, Spud and Bean Tracks	
Torrington	Stock and House Tracks	
Lingle	Elevator Track	

TOC Home

3. Type of Operation

Main Track

MP 0.0 to MP 9.9	CTC, 2 MT
MP 9.9 to MP 43.3	CTC
MP 43.3 to MP 59.1	CTC, 2 MT
MP 59.1 to MP 85.5	CTC
MP 85.5 to MP 90.4	CTC, 2 MT

4. Subdivision Specific Rules Information

Safety Overlay Systems in Effect

- Positive Train Control (PTC) MP 0.0 to MP 46.5
- Hi-Rail Limits Compliance System (HLCS)

GCOR 5.8.4, Whistle Quiet Zone—Whistle signal 5.8.2(7) is not required at the following crossing locations. All other whistle requirements remain in effect.

Location	Milepost	Crossing Name
Scottsbluff, NE	30.06	9th Avenue
	30.34	5th Avenue
	30.81	Broadway
	31.02	Avenue B
	31.47	20th Street
	31.71	Avenue I
Torrington, WY	59.73**	CR 53D
	60.75**	CR 66C/Lift Station Rd
	62.00**	US 85/Main Street
	62.27**	C Street
	62.98**	B70/Radio Rd
	63.43**	CR 47/Golf Course Rd
	64.83**	F45/McKenna Rd
Lingle, WY	71.65**	WYO State Hwy 156

**Automated Horn System - The AHS is activated by the approaching train which sounds a warning in conjunction with the automatic crossing devices. When the crossing signals are activated the AHS will automatically sound horn at crossing.

To confirm AHS is functioning, an indicator flashes at the crossing. After indicator is observed to be flashing, whistle signal Rule 5.8.2(7) is no longer required.

The train horn must be sounded if the wayside horn indicator is not visible approaching the crossing or if the wayside horn indicator, or an equivalent system, indicates that the system is not operating as intended.

GCOR/MWOR 6.19, Flag Protection—When flagging is required, distance will be 2.0 miles.

Helping Stalled DP Trains—Stalled distributed power trains that must add helpers to the head end of the train under the direction of the specific subdivision Operating Officer are to operate as outlined below.

ABTH Rules 102.11, 102.11.3, and 102.11.4 are amended only for this move to read:

ABTH 102.11, Helper Operations—When adding helpers to the head end of a DP train, the control of all locomotives coupled together must be transferred to the DP road locomotive engineer by plugging in the MU cable, whenever practicable. When more than one locomotive is attached to a train, the engineer of the DP road locomotive must control the train's air brakes. The engineer in the lead locomotive consist is in charge of train movement. The engineer in charge will communicate with and direct the engineer on the DP road locomotive as follows:

1. Identify speed restrictions and locations where a stop is to be made at least 2 miles in advance.
2. Communicate clearly the name or aspect of signals affecting the train's movement as soon as the signals become visible or audible.

Note: The helper engineer will be responsible to comply with whistle requirements and may utilize the ABV handle, even though cut out, to initiate an emergency application of the brakes should any emergency situation occur requiring this action. The speed limit for a train in this configuration must not exceed 20 MPH.

ABTH 102.11.3, Adding Manned Helper to Head End of Train—When a manned helper is coupled on the head end of the train, the helper engineer will transfer control of the air brakes (and the throttle with MU cable) to the road engineer as follows:

1. Before opening angle cocks between the road locomotive and the manned helper, the engineer on the helper locomotive will:
   a. Communicate with the road engineer to determine the brake pipe reduction currently applied to the train.
   b. The helper engineer must make a reduction 2 psi more than the current reduction applied to the train.
   c. After brake pipe exhaust has ceased, cut out the automatic brake valve and place handle in the release position.
   d. Notify the engineer on the road locomotive of the amount of the brake pipe pressure reduction
   e. The independent brake valve must be left cut in on the helper locomotive. Place the independent brake valve handle in the release position and actuate to fully release the brakes on the helper locomotive consist.
2. The engineer on the road locomotive will:
   a. After opening the angle cocks between the helper and the road locomotive, increase brake pipe reduction to at least 20 psi and helper crew will observe that brakes apply on helper consist by visual inspection.
   b. When train is ready to depart, perform DP train check to check brake pipe continuity as brakes are released as per ABTH Rule 105.4 Also observe by visual inspection that brakes release on helper consist.

ABTH 102.11.4, Removing Manned Helper from Head End of Train—When a manned helper will be detached from the head end of the train do the following:

1. The engineer in control of the road locomotive will:
   a. Make not less than a 6 psi brake pipe reduction.
   b. Notify the helper engineer when ready to detach the manned helper after closing the angle cocks between the helper consist and the road locomotive and removing the MU cable.
2. The helper engineer will cut in the Automatic Brake Valve after the angle cocks are closed between the consists.
3. After the helper consist is detached, the Engineer on the road locomotive will increase the brake reduction on the train to not less than 15 psi before the train departs.

TOC Home

5. Trackside Warning Devices (TWD)

MP	Device	Recall Code	Notes
Type B.Locations			
2.4	DED		Exception reporting
9.9	DED		Exception reporting
20.5		818	Exception reporting
42.3		817	Exception reporting
46.7	DED		Exception reporting
50.9	DED		Exception reporting
55.0	DED		Exception reporting
59.9	DED		Exception reporting
65.9		828	Exception reporting
72.6	DED		Exception reporting
76.8	DED		Exception reporting
82.9		838	Exception reporting

6. FRA Excepted Track—None

7. Special Conditions

Scottsbluff Yard—The inside crossover switch located at the east end of Scottsbluff Yard at MP 29.4 must be left lined and locked for movement to the Factory Lead except for immediate movement to or from the Main Track per GCOR 8.12.

The high stand switch will display a red target when lined for movement to or from the Main Track. Authority to occupy the Main Track must be secured before lining this switch for Main Track movement.

Scottsbluff Local Crossing Ordinance—A standing train must not block a crossing for more than five minutes. A moving train must not block a crossing for more than ten minutes.

Scottsbluff Eastward Freight Trains—When picking up cars at Scottsbluff, Nebraska, fill train to 1.0 HPT. Trains consisting of only four-axle locomotives will require 1.3 HPT. Do not depart Scottsbluff, Nebraska with less than required HPT without prior approval of Train Dispatcher.

Bad Order Setout Tracks—Tracks at the following locations are designated as bad order setout tracks. Signs indicate where car(s) should be spotted:

Location	Track No.	Track Name
Henry	2197	Bennet back track
Torrington	2304	R&M Lumber
Lingle	2502	Elevator track

Empty Cars in Loaded Grain Trains—Empty cars will not be handled in loaded grain trains on the Valley Subdivision. If empty cars are located in the train, notify the Train Dispatcher before switching them out.

HazMat Cars—Conductors of trains relieved or tied down on line must leave a copy of the wheel report and a list of any cars that were picked up on line in the lead locomotive. This will ensure that the relieving crew will have the proper shipping paper for any HazMat cars in the train for movement into the terminal. It will be the relieving conductor’s responsibility to turn in the required paperwork for reporting at the final terminal.

In the event HazMat car(s) are in-trained without the proper shipping papers, a hazardous material radio waybill will be filled out for movement. This information can be obtained from the Train Dispatcher or Field Support using option #3 on the radio call in.

Excessive Wind Warnings—The first sentence of System Special Instructions, Item 33 is amended to read: When wind warnings in excess of 60 MPH are received, the train dispatcher will notify all trains and employees with movement authority in the area, providing the time and limits of the expected high winds.

Close/No Clearance Locations

Location	Track Name	Track No.	Obstruction
Bayard	Bean Track	1201	Buildings
	Simplot	1202	Buildings, tanks
Minatare	Stock Trk	1401	Buildings, piping, tripping hazard
	House Trk	1402	Buildings
Scottsbluff	Western Sugar	1611, 1612	Buildings, piping
		1613	Tripping hazard
		1614	Molasses tanks
	Otoe Lumber	1608	Building
	Slafter Oil	1607	Loading dock, overhead cables
	Scottsbluff Recycling	1615, 1616	Fencing, buildings, tripping hazard
	Kelley Bean	1617, 1618	Elevator, poles
	Hebert Milling	1619, 1620	Elevator, buildings
Mitchell	Kelley Bean	1804	Buildings
Morril	Pass track	2001	Elevator, buildings
	Stock track	2002	
	Jirdens/ Westco	2003	
	House track	2004	
	Spud track	2005	
	Bean track	2006	
Torrington	Z&W Mill track	2302	Loading dock, elevator, buildings
	House track	2303	
	Orphan track	2304	
Lingle	Kelley	2502	Buildings

Test Miles

MP 1.0 to MP 2.0
MP 8.0 to MP 9.0
MP 28.0 to MP 29.0
MP 49.0 to MP 50.0
MP 74.0 to MP 75.0
MP 91.2 to MP 92.2

SSI—Switch Control/Monitoring Systems

- Turnouts Equipped with Two Switch Machines (Movable Point Frogs/Swing Nose Frogs/Derail):
  - Northport
  - MP 2.4, crossover
  - MP 6.7, crossovers
  - Atkins
  - Enterprise
  - Stuart
  - MP 82.2 CP 822
  - MP 83.5 CP 835
- ICS—in effect
  - Northport *
  - MP 2.4, crossover *
  - MP 6.7 *

* Denotes all crossover switches within Control Point are ICS.

Flash Flood Critical Areas

MP 2.0 to MP 67.0

TOC Home

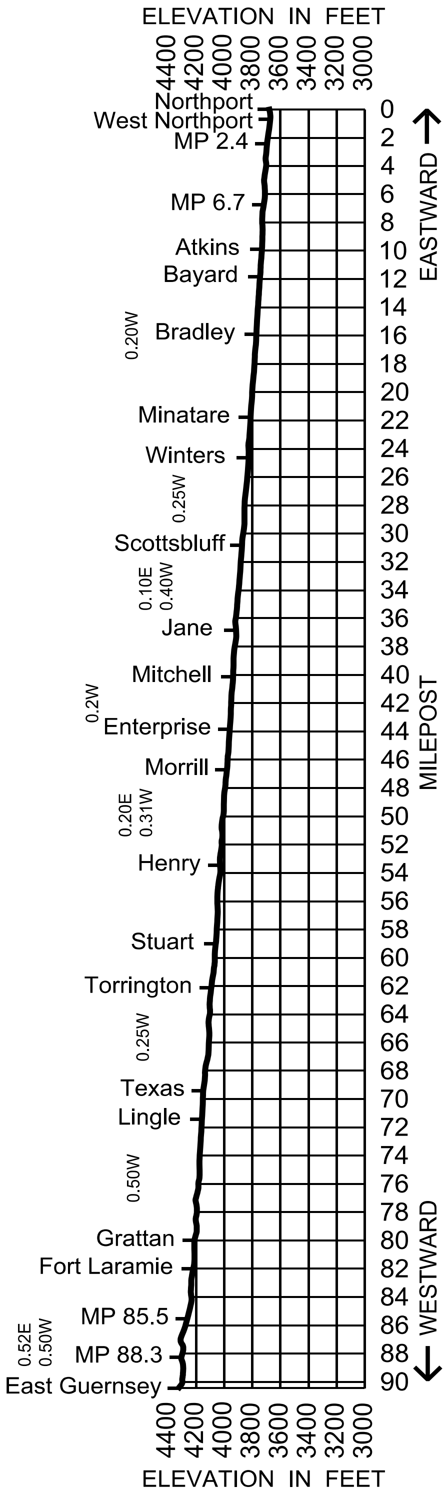
8. Line Segments

Segment No.	Limits	Milepost
Road Line Segments		
5	Northport to E Guernsey	MP 0.0 to MP 90.4
Yard Line Segments		
896	Scottsbluff	

9. Other Location Information

Station No.	Name	Mile Post	Capacity in Feet	Switch Opens
32034	South Storage 101 - MT2	1.0	6,500	Both
32037	Progress Rail Trks 102 - 105 - MT2	2.4	6,000	West
32046	Bayard Track Siding 1298	12.0	5,150	Both
32046	Bayard Bean Trk 1202	12.0	1,300	West
32046	Bayard Sugar Factory W Wye Trk 1204	12.0	6,950	West
32056	Minatare Siding 1498	21.7	5,650	Both
32056	Kelly Bean Spur 1403	22.7	250	West
32056	Minatare North House Trk 1402	21.7	1,950	Both
32065	Scottsbluff 1601	30.0	2,200	Both
32065	Scottsbluff 1602	30.0	2,150	Both
32065	Scottsbluff 1603	30.0	2,000	Both
32065	Scottsbluff 1604	30.0	2,000	Both
32074	Mitchell Old Pass 1801	41.0	6,100	Both
32074	Mitchell 1802	41.0	1,450	Both
32074	Mitchell 1803	41.0	1,400	Both
32074	Sugar Factory 1808	41.0	7,850	East
32080	Morrill Bean Trk 2006 - MT2	46.4	1,700	East
32080	Morrill House Trk 2004 - MT1	46.8	3,700	Both
32080	Morrill Old Pass 2001 - MT1	47.2	2,600	West
32088	Henry 2101	53.7	3,050	West
	Bennett Back Trk - MT2	50.6	1,500	Both
32096	R&M Lumber 2304	61.7	650	East
32096	Torrington No Siding 2301	62.5	2,600	Both
32106	Lingle Pass 2501	72.6	3,900	Both
32116	Ft Laramie Back Trk 2798	81.5	1,750	East
32116	Ft Laramie Oil	82.9	Loop trk	Both

10. Grade Chart



Track Chart
Angora Subdivision

Alliance, NE to Northport, NE

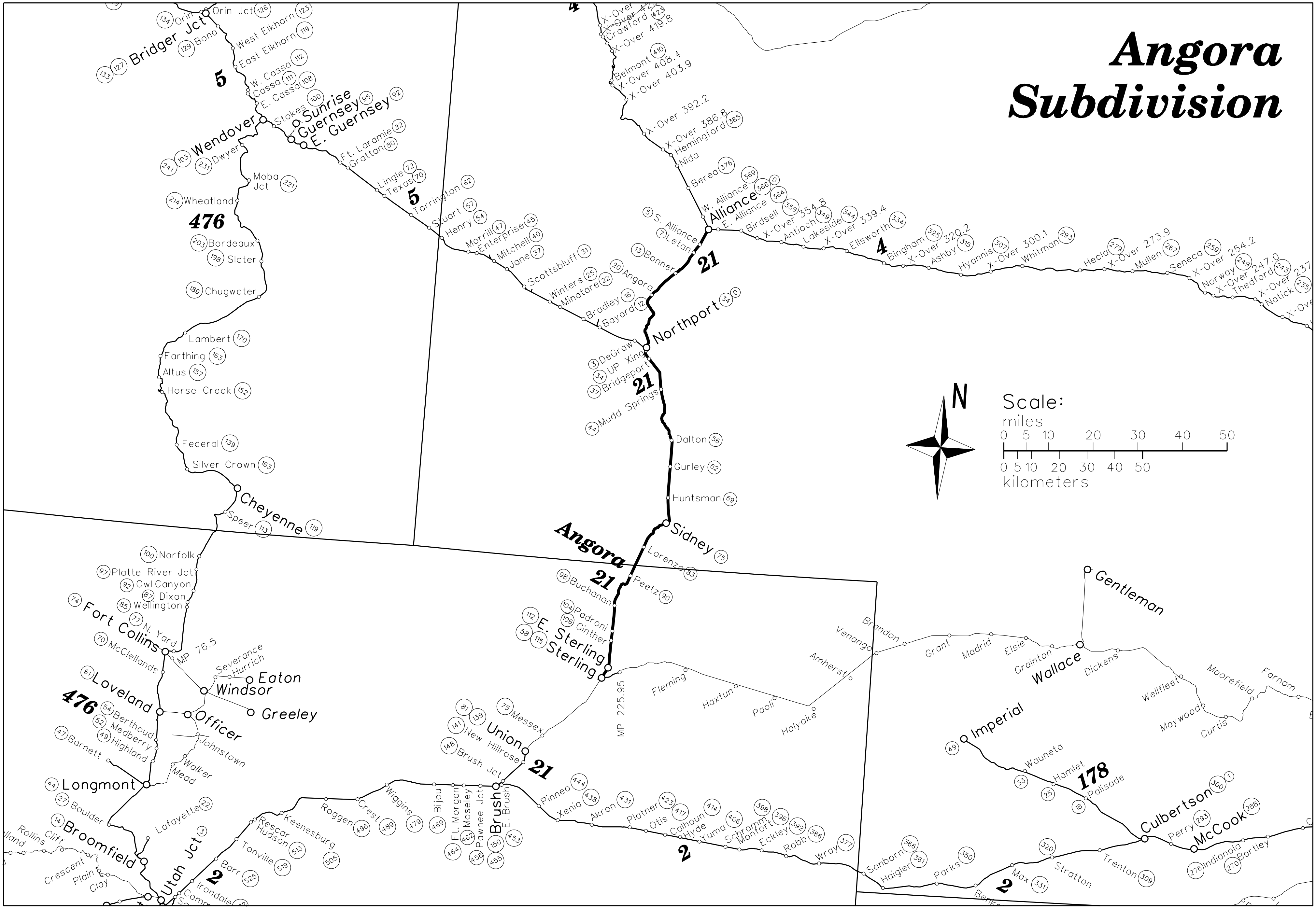
MP .3 to MP 33.826

See each page for latest revised date.

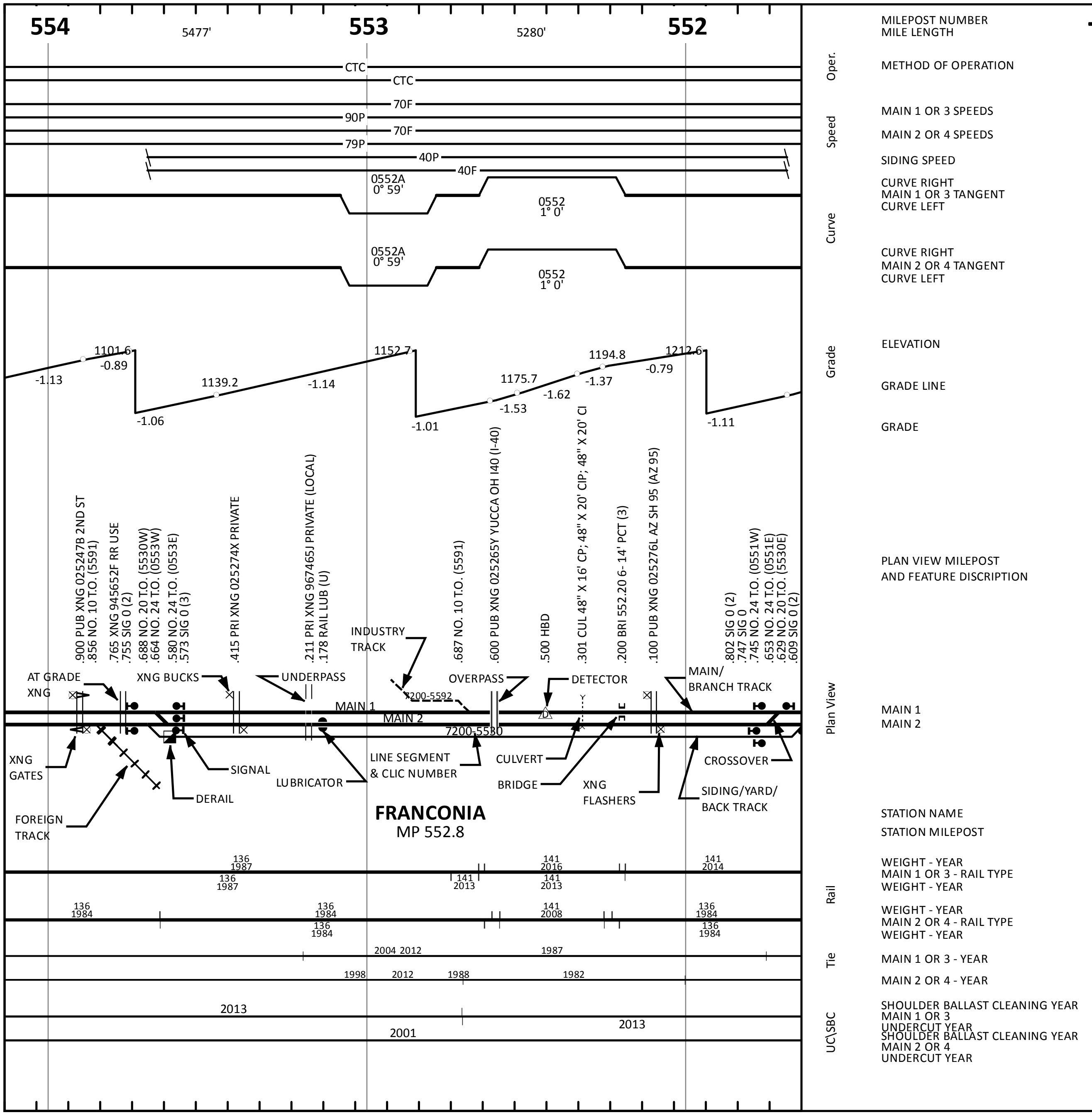
Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Angora Subdivision



TRACK CHART FEATURE LEGEND



NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280')   VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

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Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

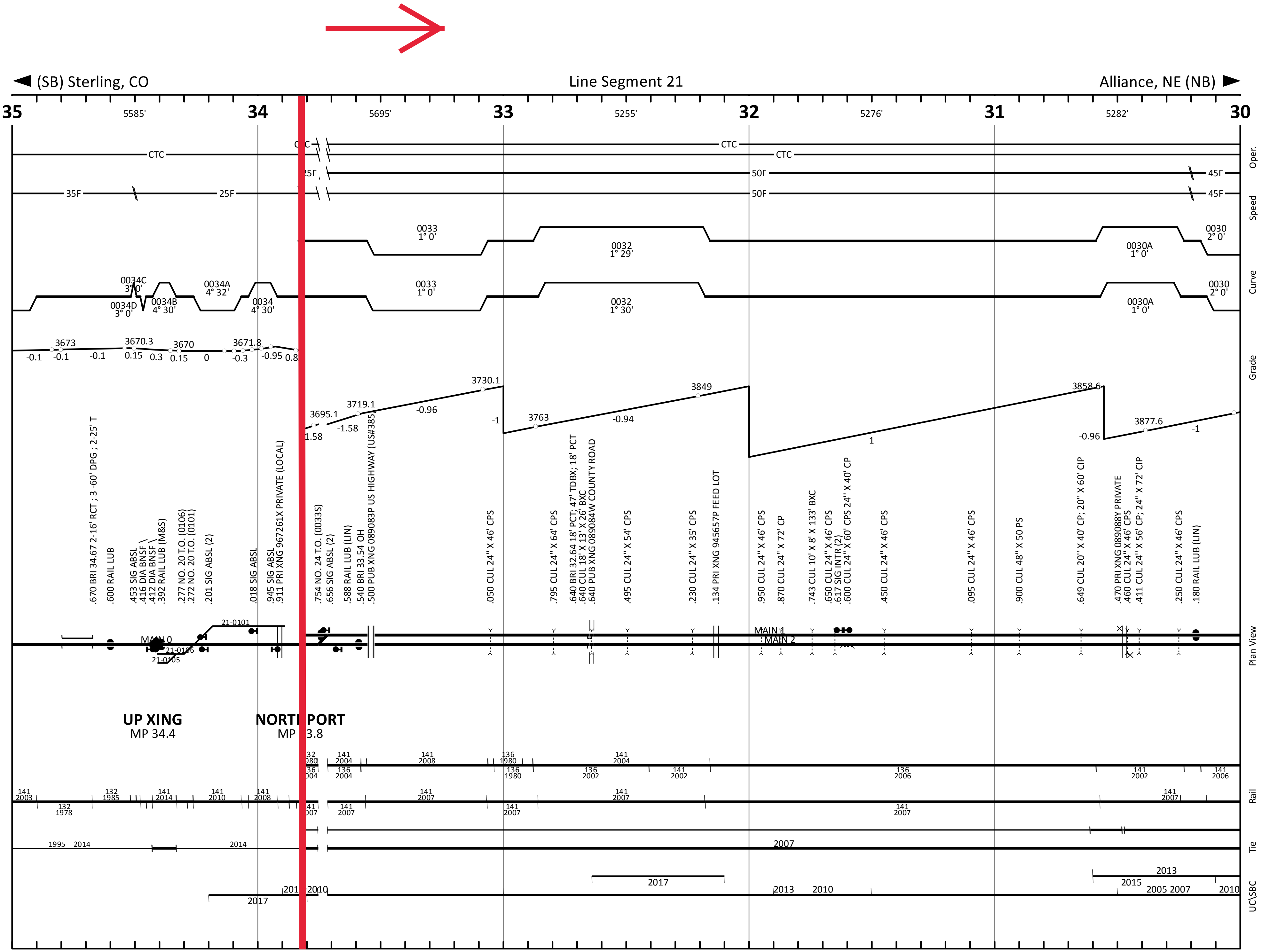
AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL



BNSF RAILWAY

System Maintenance and Planning

Angora Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

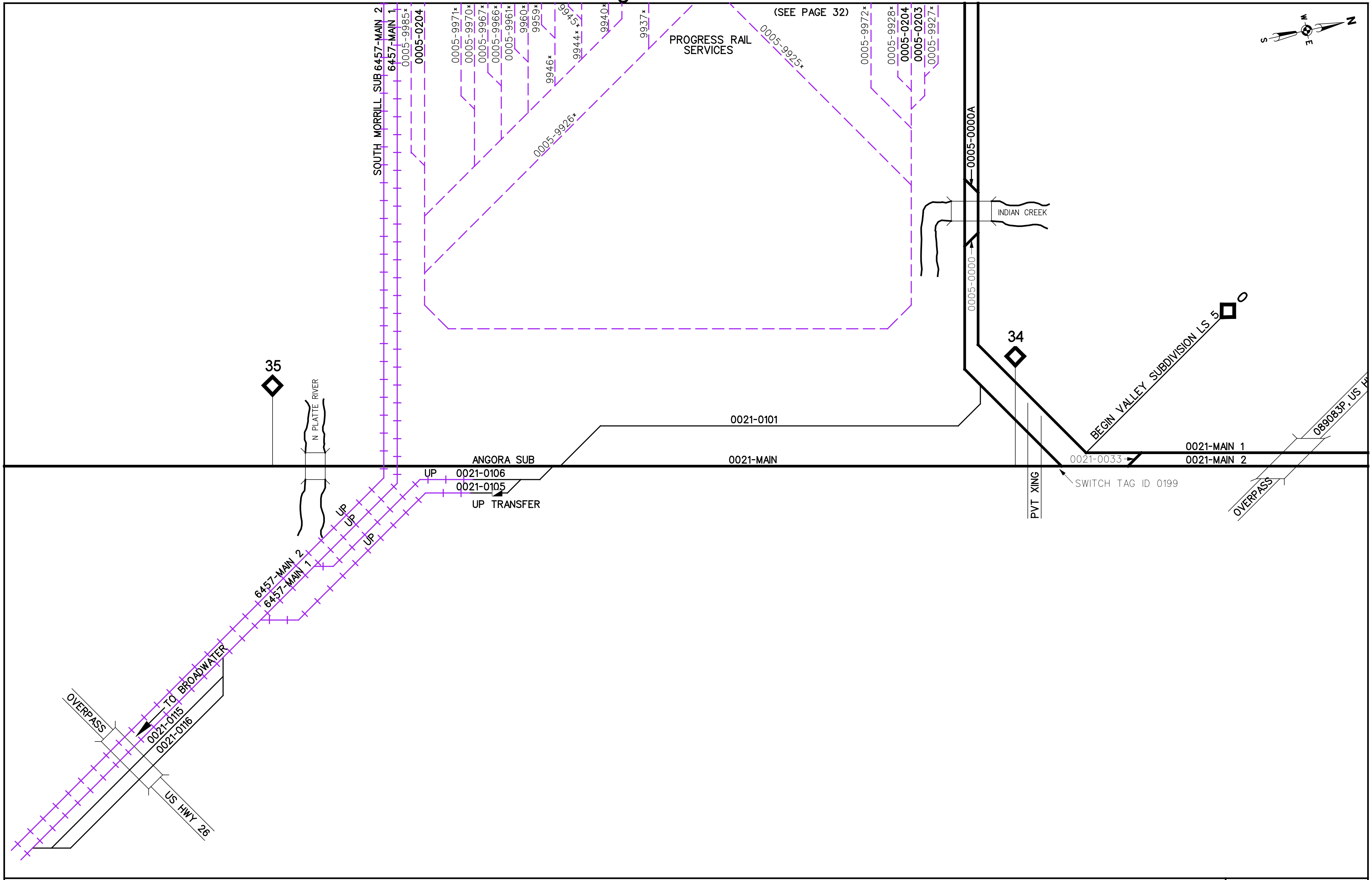
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 10, 2018

NORTHPORT, NE
Angora Subdivision

← Sterling, CO

Third St. Alliance, NE →



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

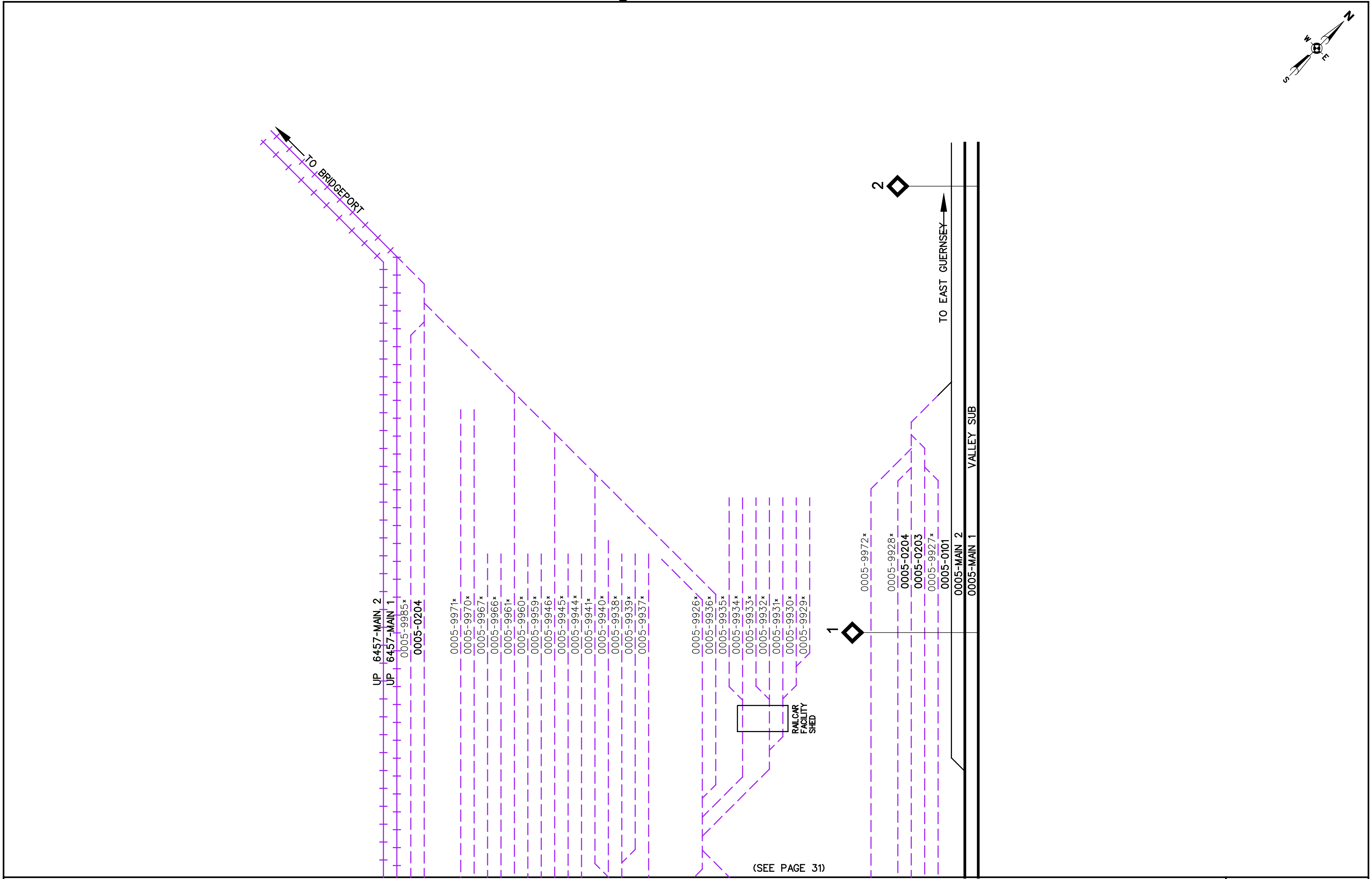
REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
SPECIAL CONDITIONS (ITEM *7)
FOR ADDITIONAL QUESTIONS ON PHYSICAL CHARACTERISTICS, CONTACT A LOCAL DIVISION MANAGER
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

———	BNSF OWNED & MAINT	—+—+—	JOINT FACILITIES
—◆—◆—	INDUSTRY OWNED & BNSF MAINT	———	TRACKAGE RIGHTS
– – – –	IND OWNED & MAINT	—+—+—	FOREIGN TRACK
—●—●—	INDUSTRY MAINT & BNSF OWNED (LEASE)		
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT		
◪	DERAIL		

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: NORTNE
FSAC: 32034
REVISED: 3/2/2015
TEAM: NORT01031.DGN
TRK CHT: ANG031.dgn

NORTHPORT, NE
Angora Subdivision



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

REFER TO DIVISION TIMETABLE FOR:
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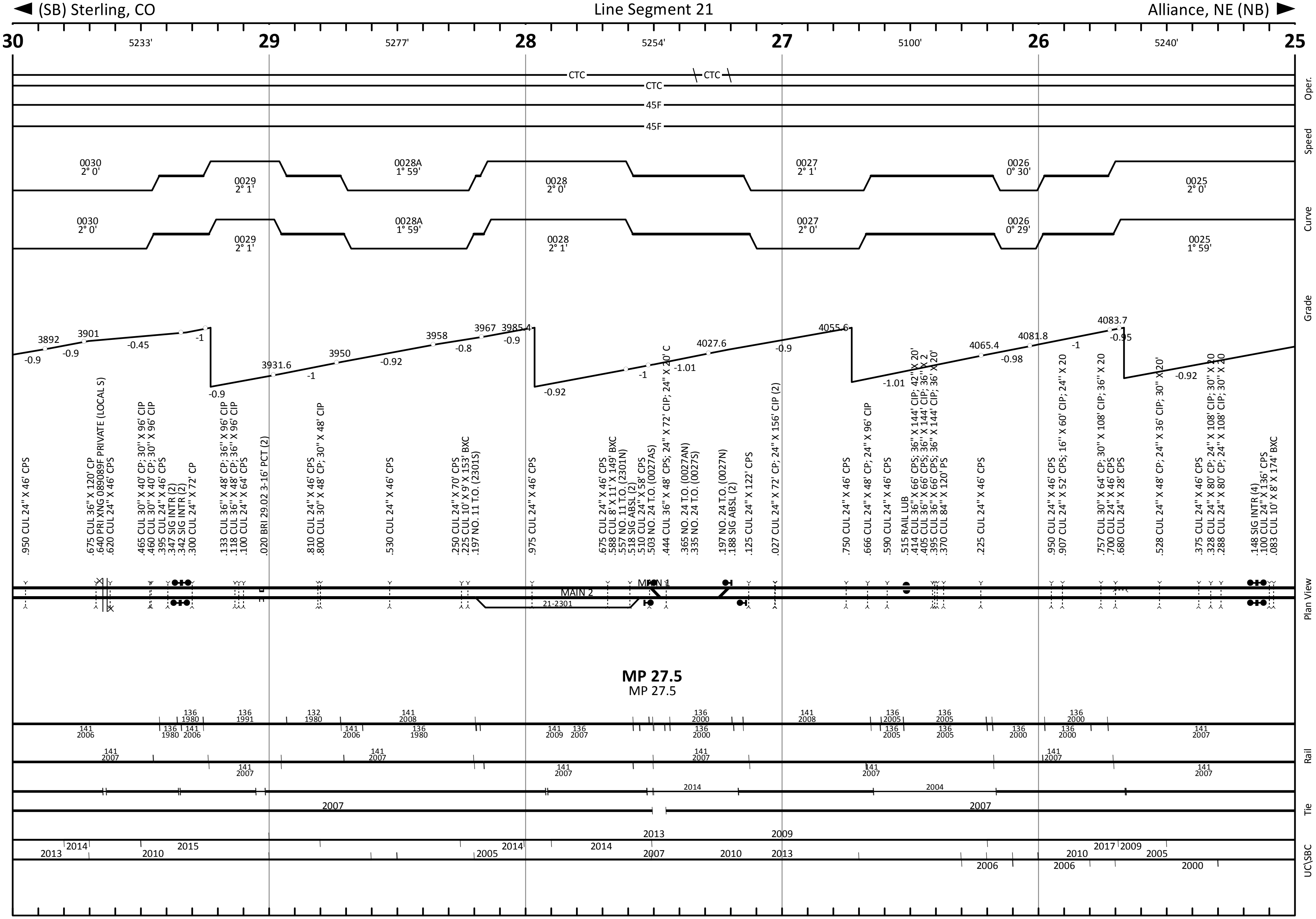
STATION ABBR: NORTNE
FSAC: 32034
REVISED: 3/2/2015
TEAM: NORT01033.DGN
TRK CHT: ANG032.dgn
TEAM PG 033



BNSF RAILWAY

System Maintenance and Planning

Angora Subdivision

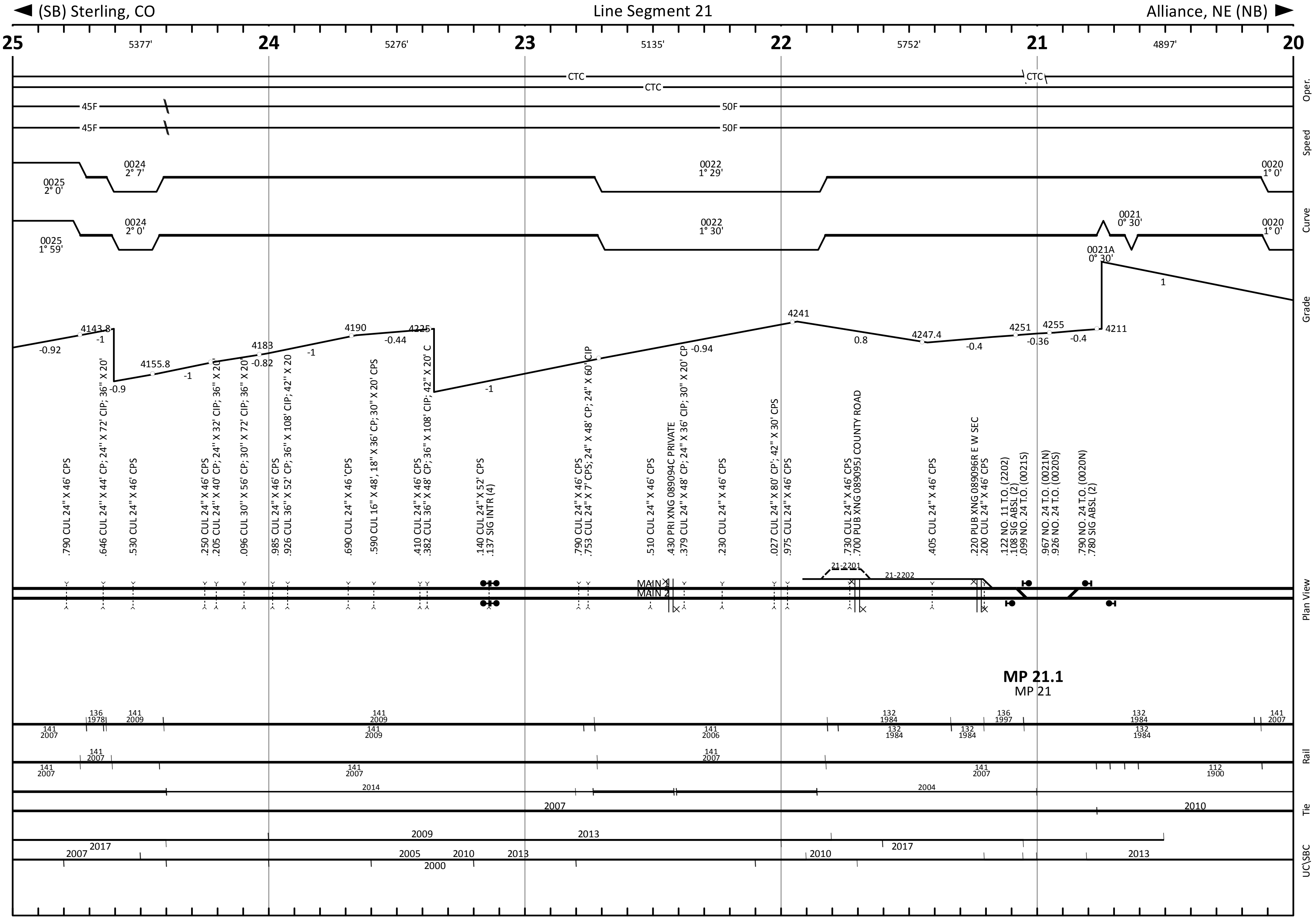
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 10, 2018 Page 33 of 41



System Maintenance and Planning

Angora Subdivision

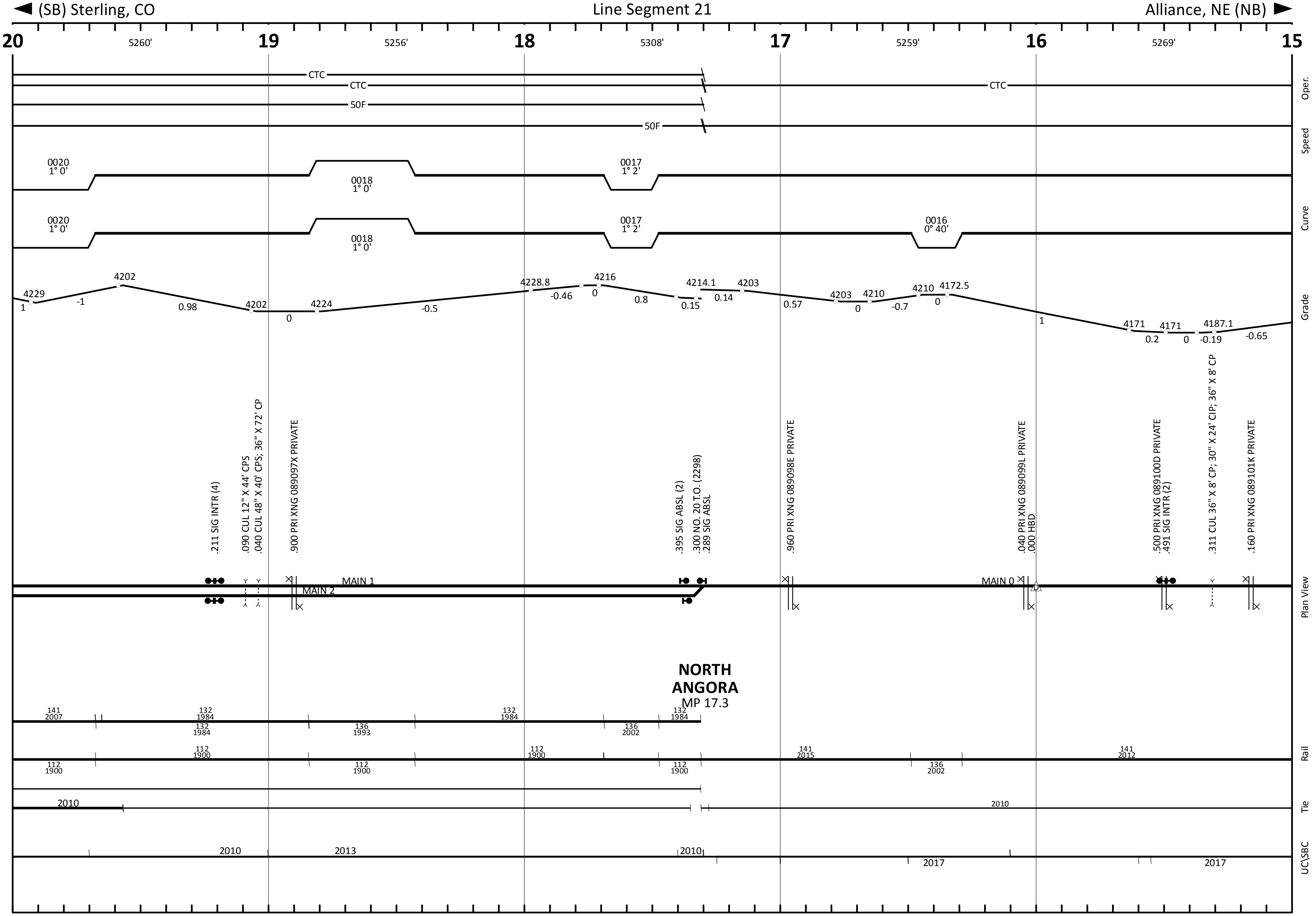
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 10, 2018



![BNSF Railway]

System Maintenance and Planning

Angora Subdivision

Powder River Operating Division

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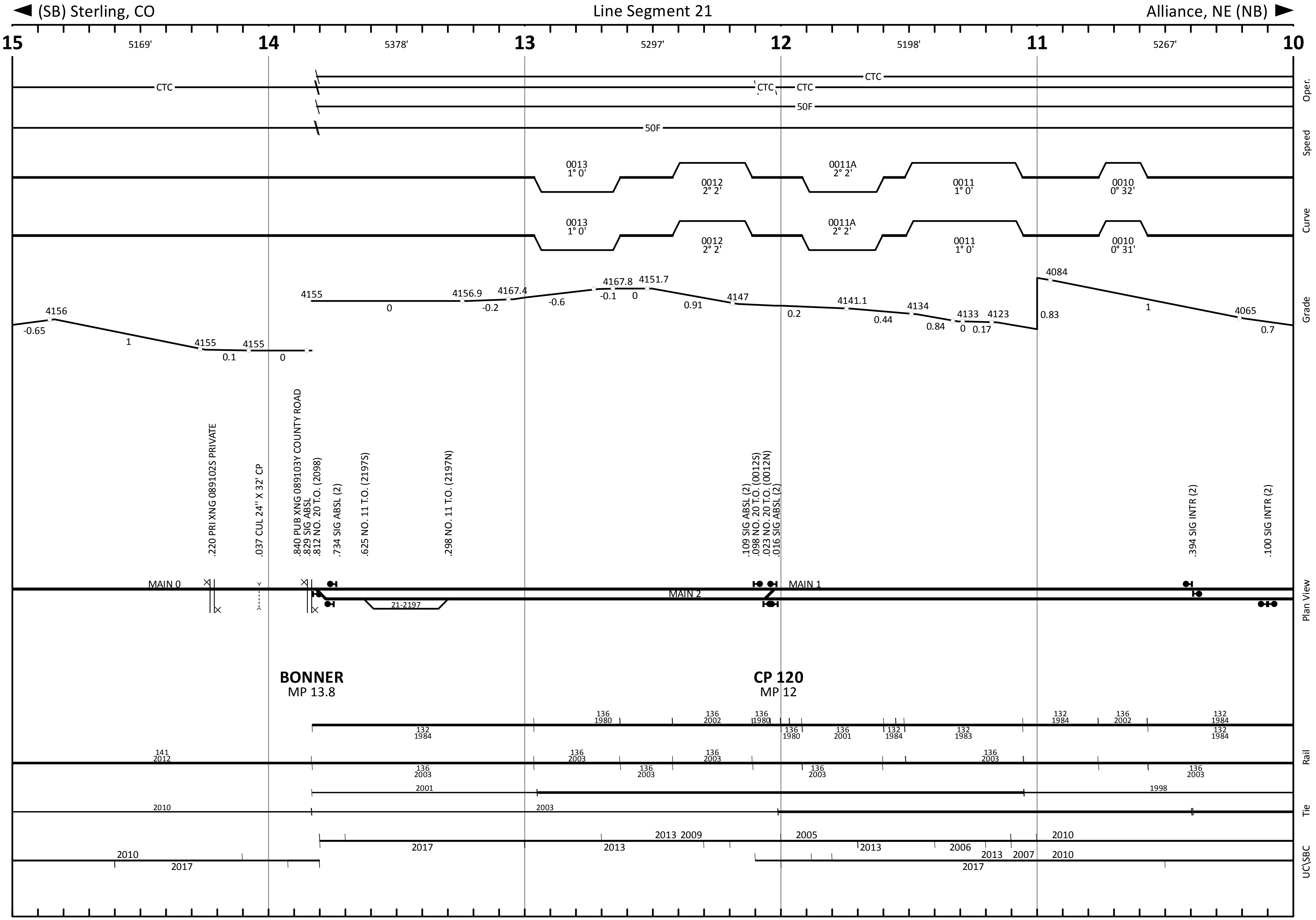
Revised to July 10, 2018 Page 35 of 41



BNSF RAILWAY

System Maintenance and Planning

Angora Subdivision

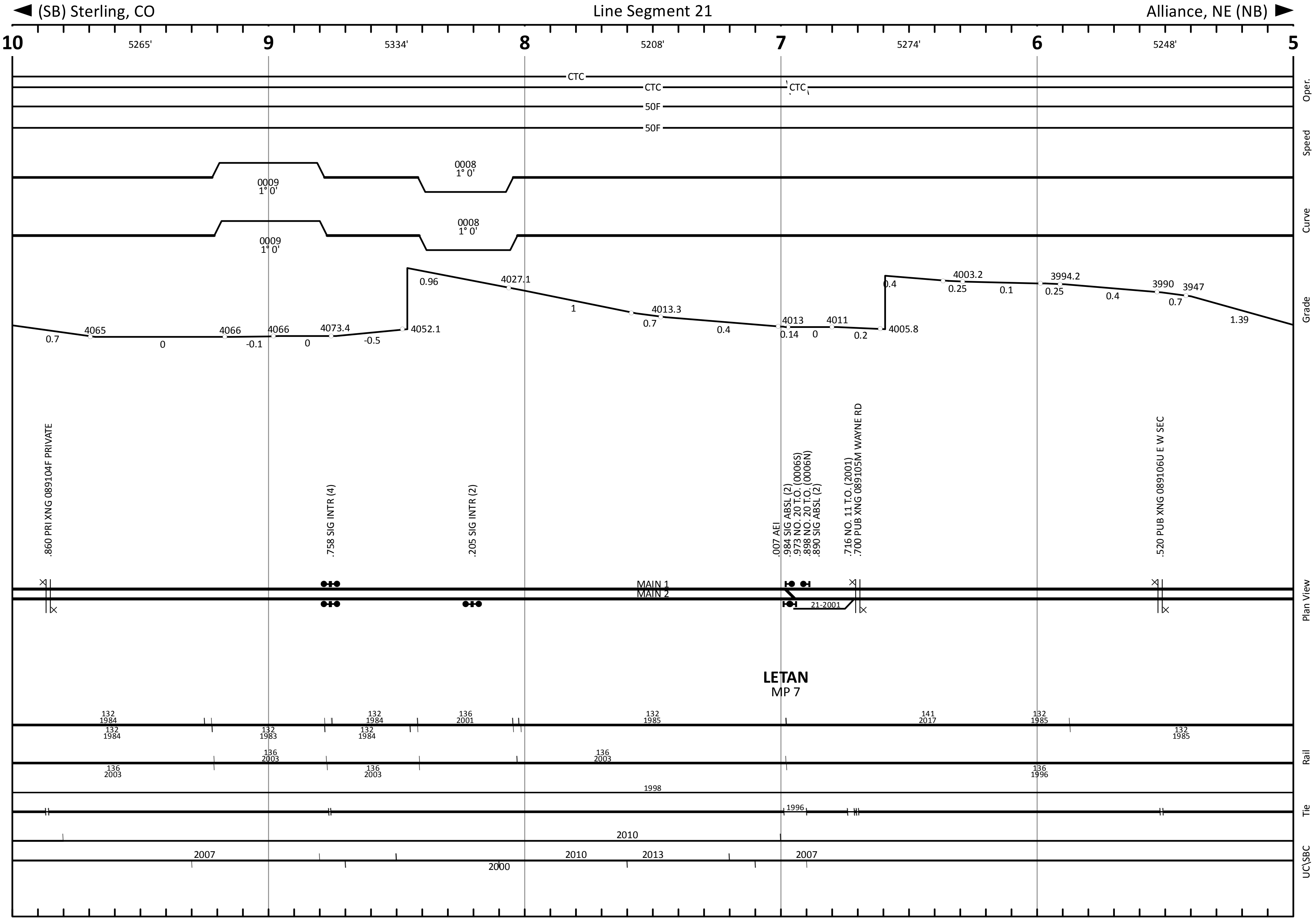
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 10, 2018 Page 36 of 41



BNSF RAILWAY

System Maintenance and Planning

Angora Subdivision

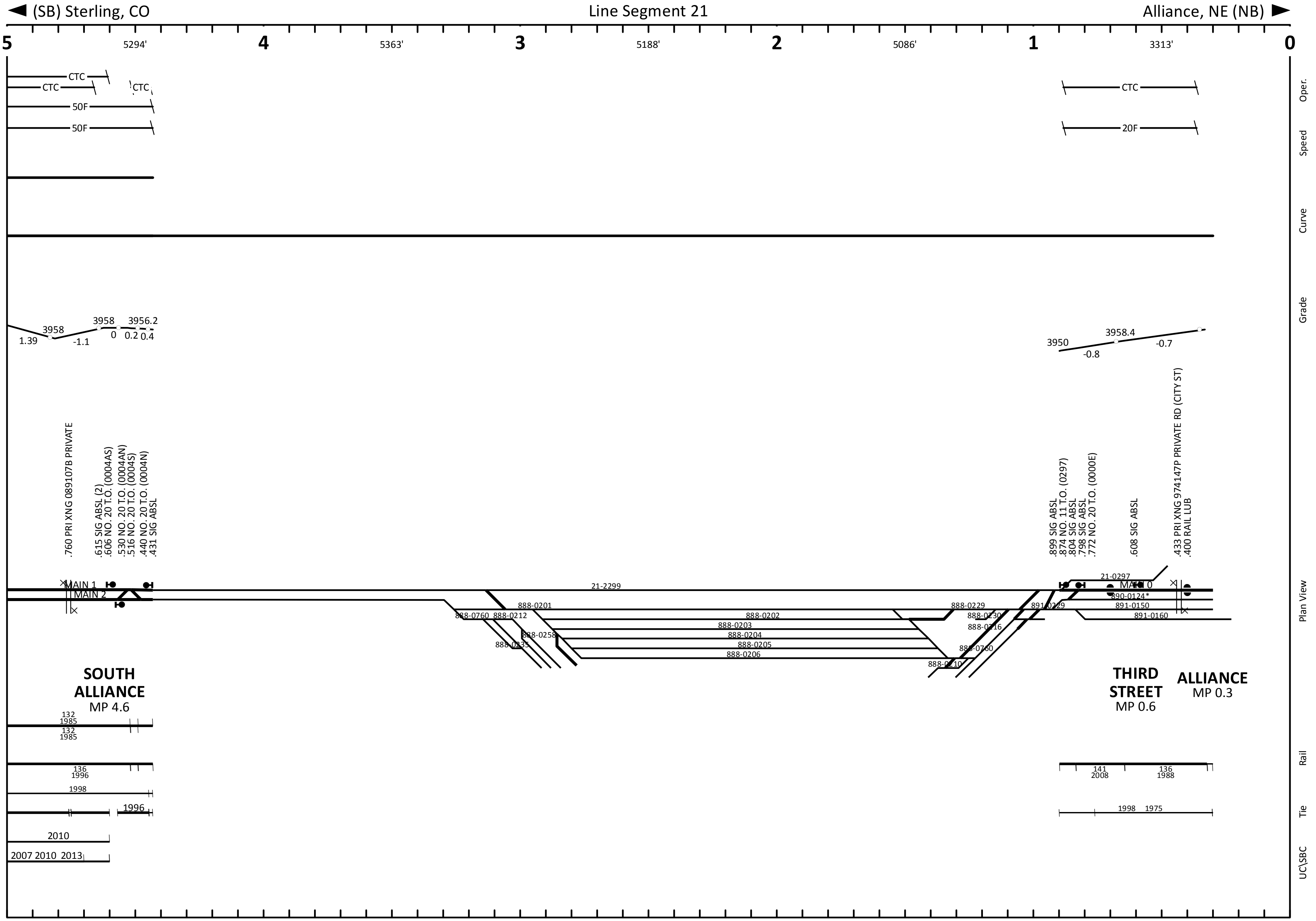
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 10, 2018



System Maintenance and Planning

Angora Subdivision

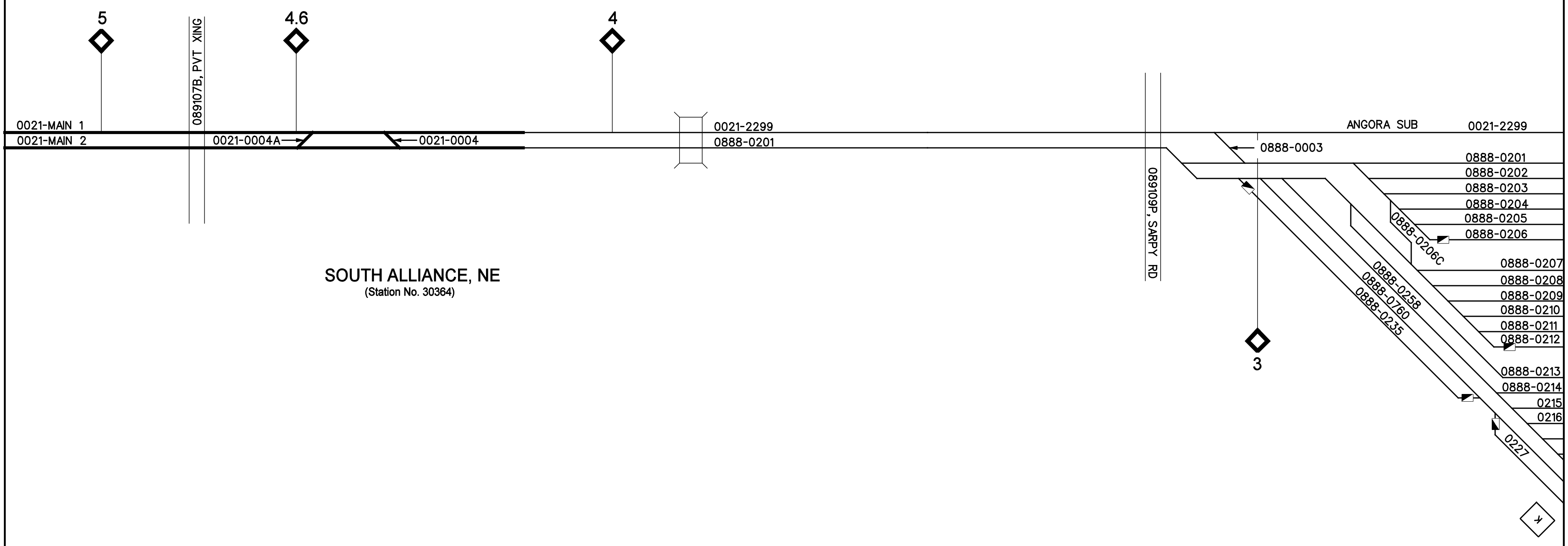
Powder River Operating Division
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 10, 2018

ALLIANCE, NE
Angora Subdivision

← Sterling, CO   Edgemont, SD →



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INDUSTRY OWNED & BNSF MAINT
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INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

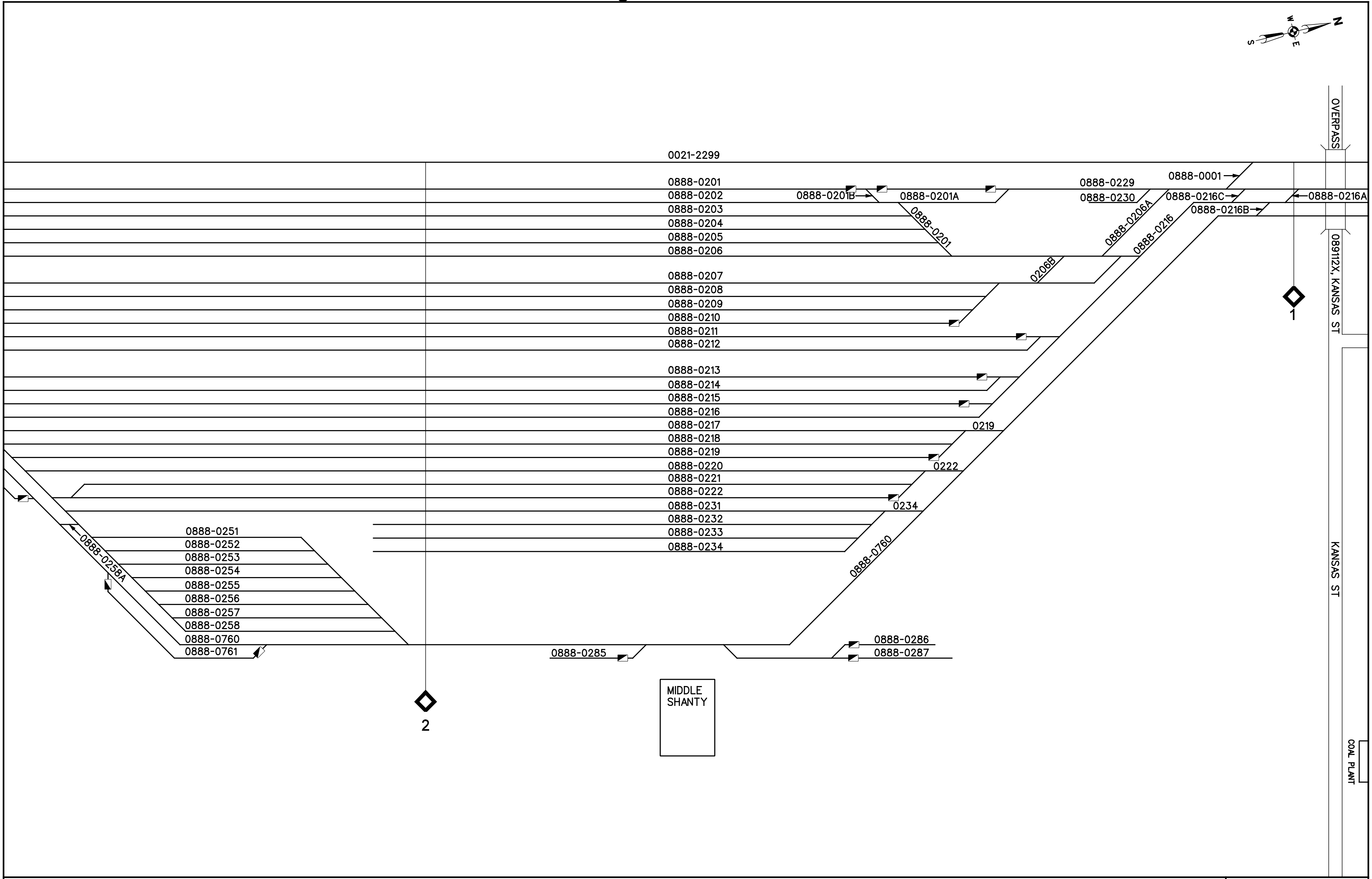
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/28/2016
TEAM: ALLI03043.DGN
TRK CHT: ANG039.DGN

ALLIANCE, NE
Angora Subdivision

← Sterling, CO

Edgemont, SD →



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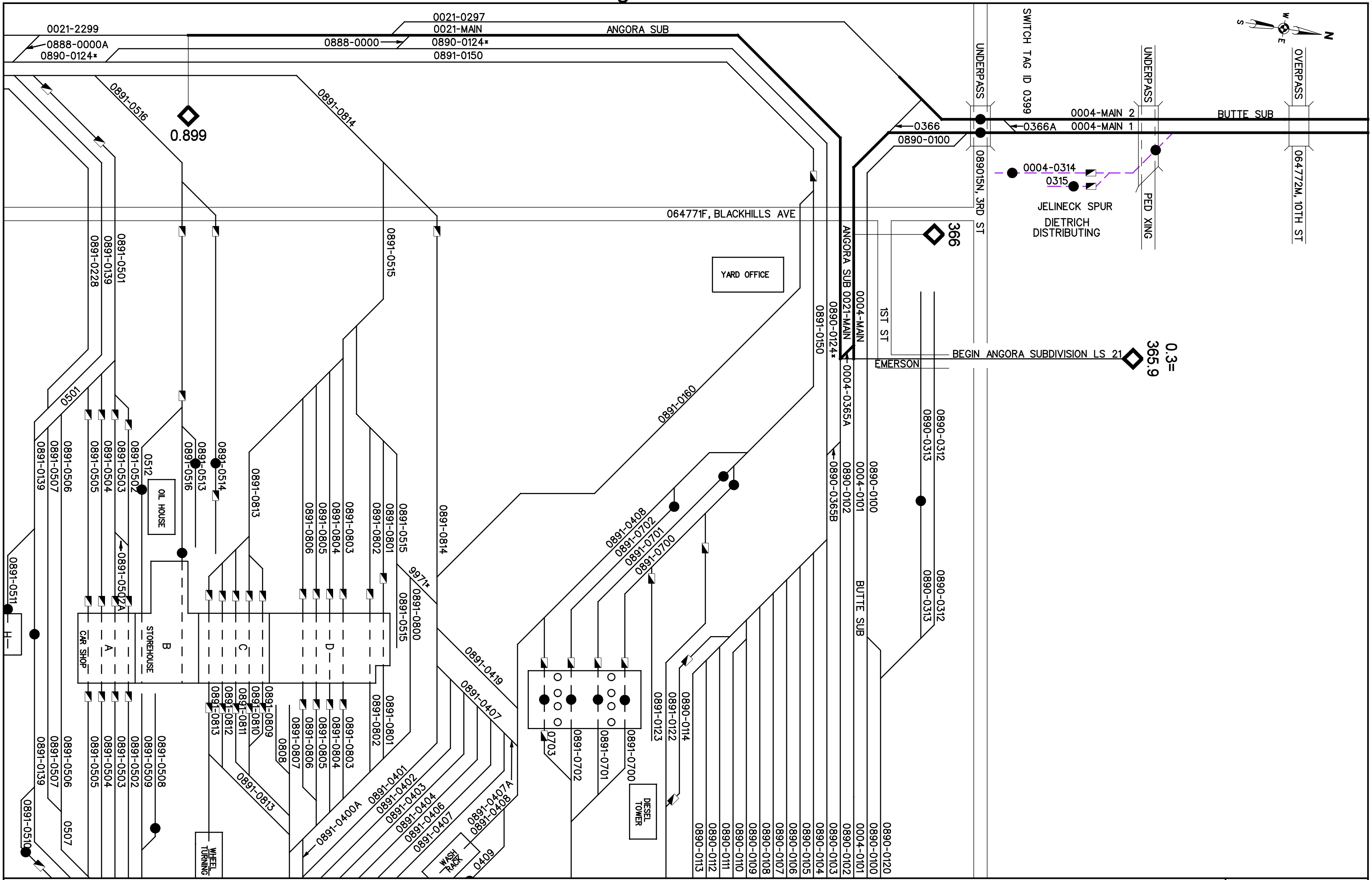
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/27/2016
TEAM: ALLI02045.DGN
TRK CHT: ANG040.DGN
TEAM PG 045

ALLIANCE, NE
Angora Subdivision

← Sterling, CO   Edgemont, SD →



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IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/28/2016
TEAM: ALLI01049.DGN
TRK CHT: ANG041.DGN
TEAM PG 049

BNSF RAILWAY

Track Chart
Black Hills Subdivision

Edgemont, SD to West Gillette, WY

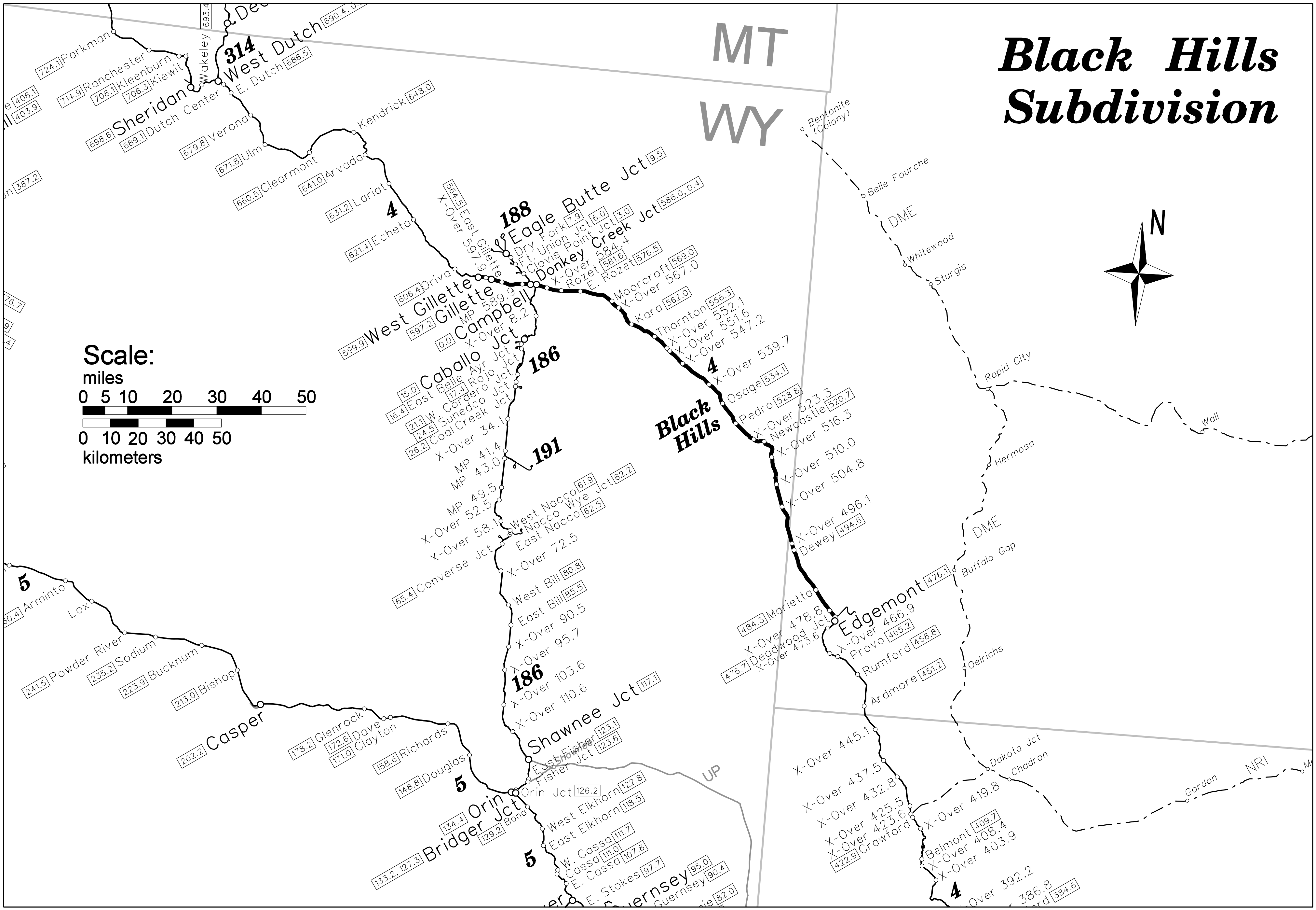
MP 476.1 to MP 586.286

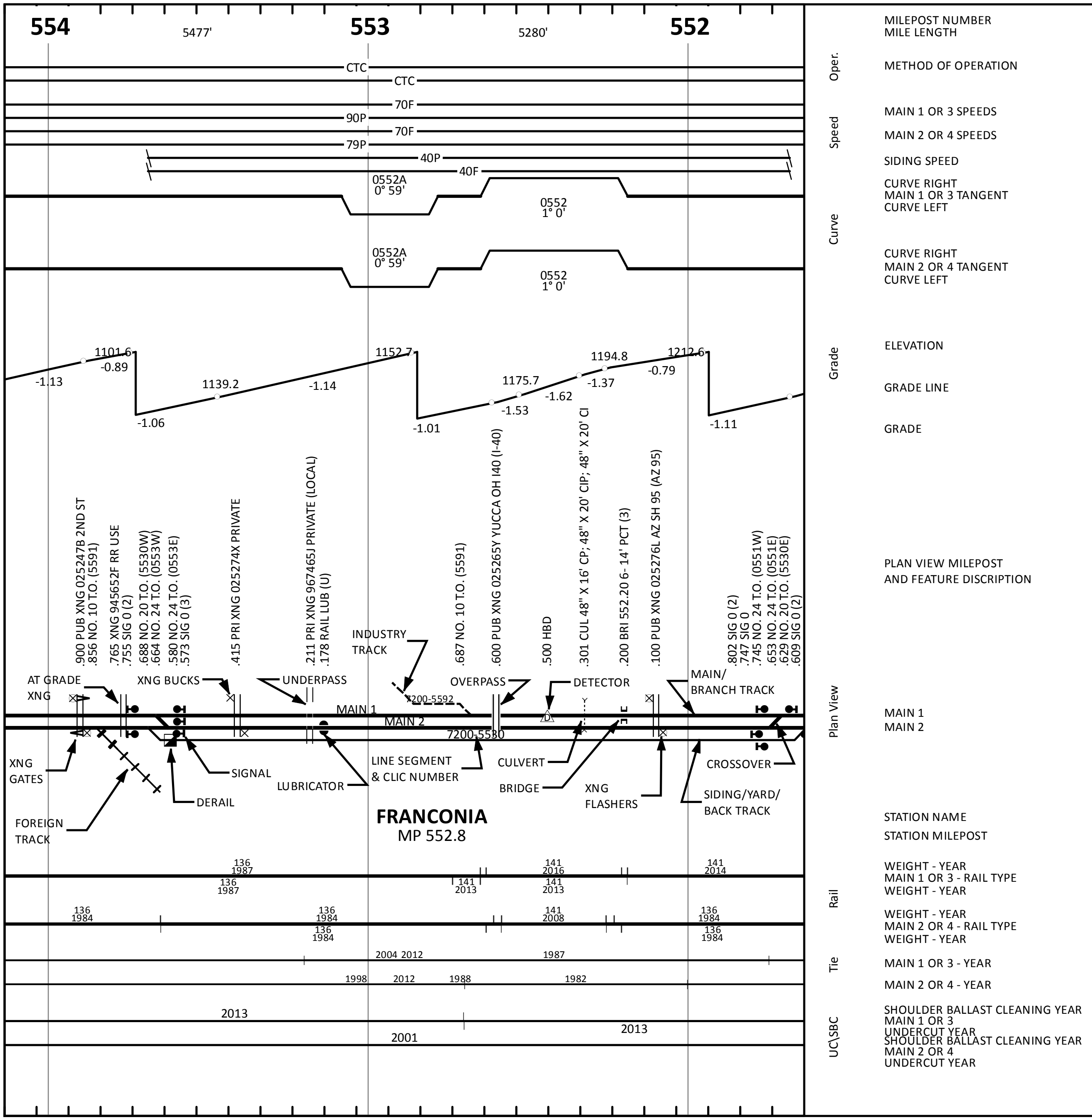
See each page for latest revised date.

Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Black Hills Subdivision





TRACK CHART FEATURE LEGEND

NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280')   VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

FILE: Y:\drawings\trkchrts\ASTC\MXD_Files\TC_Legend.mxd

Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

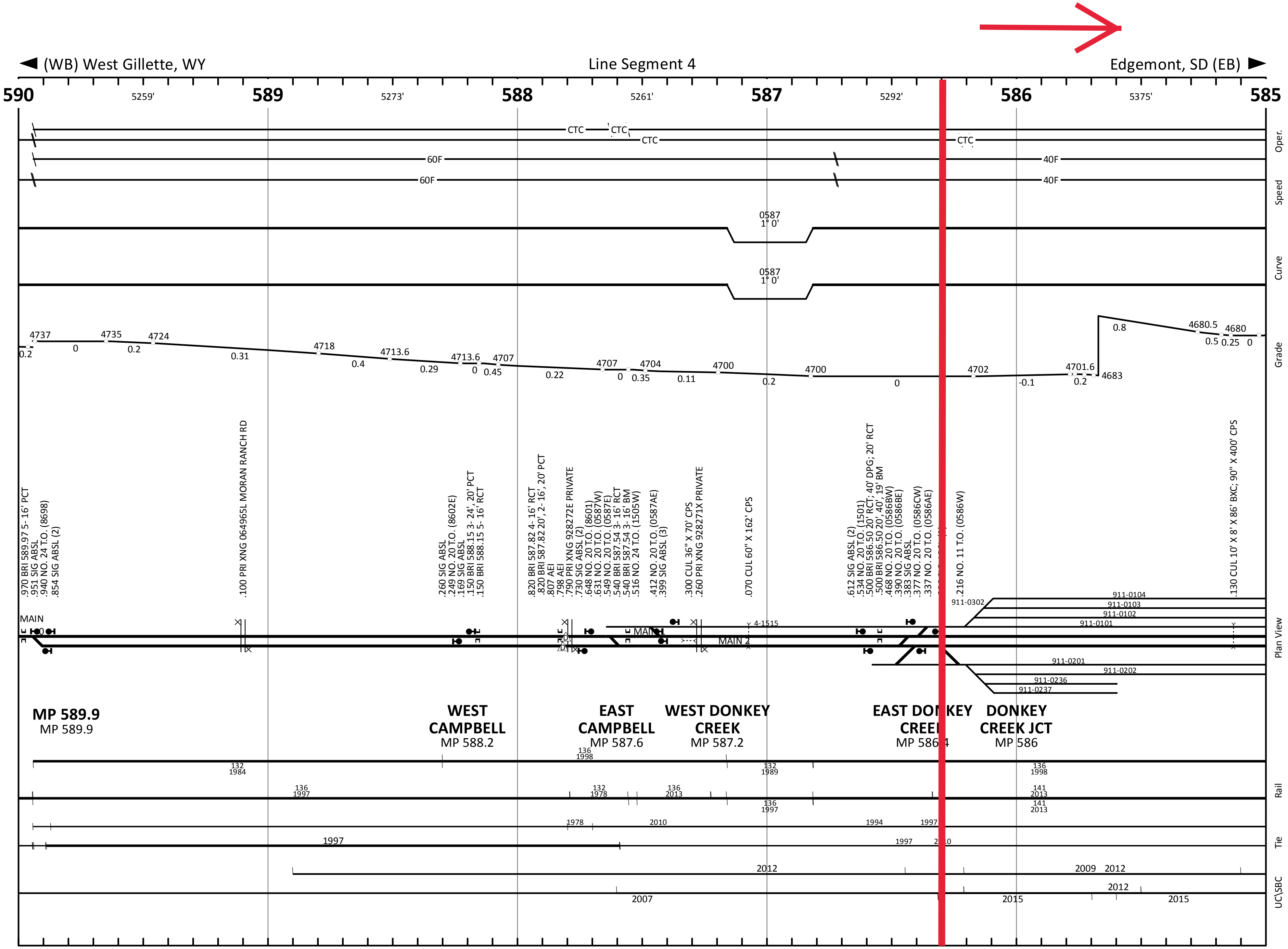
AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
Powder River West Engineering Division

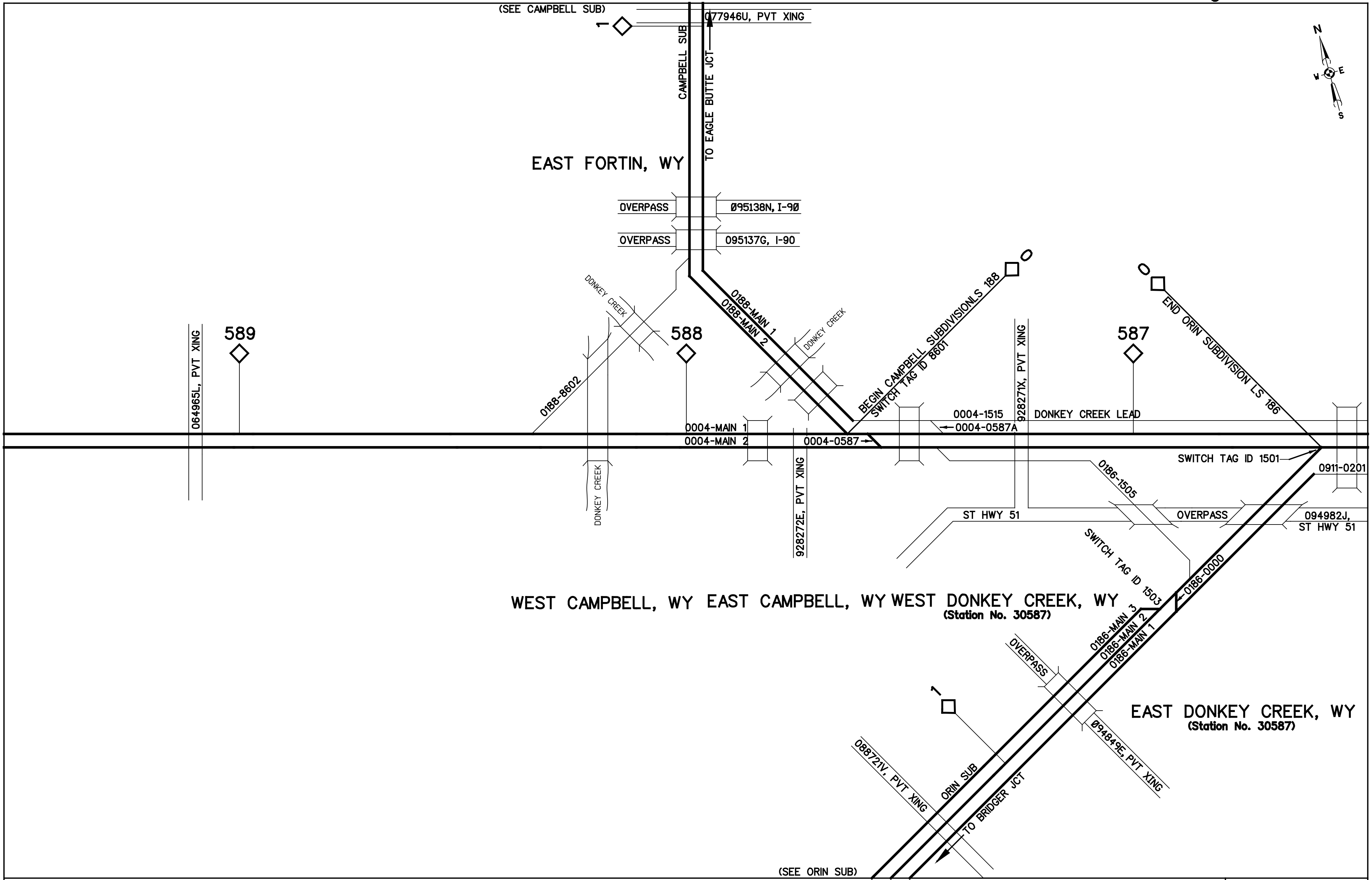
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018

CAMPBELL, WY
Black Hills Subdivision

← West Gillette, WY

Edgemont, SD →



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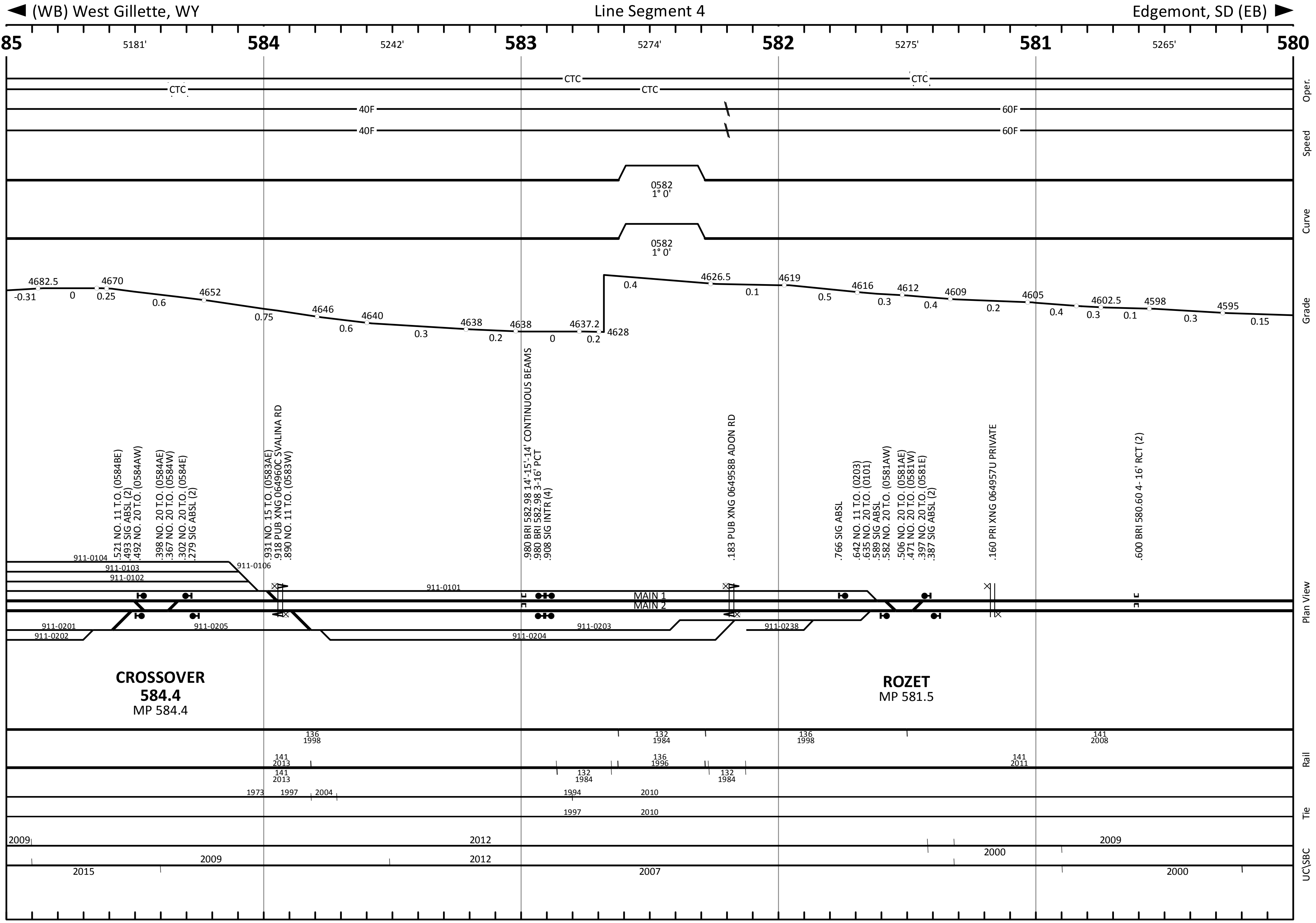
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: CAMPWY
FSAC: 30588
REVISED: 8/22/2017
TEAM: CAMP02009.DGN
TRK CHT: BLK011.DGN



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

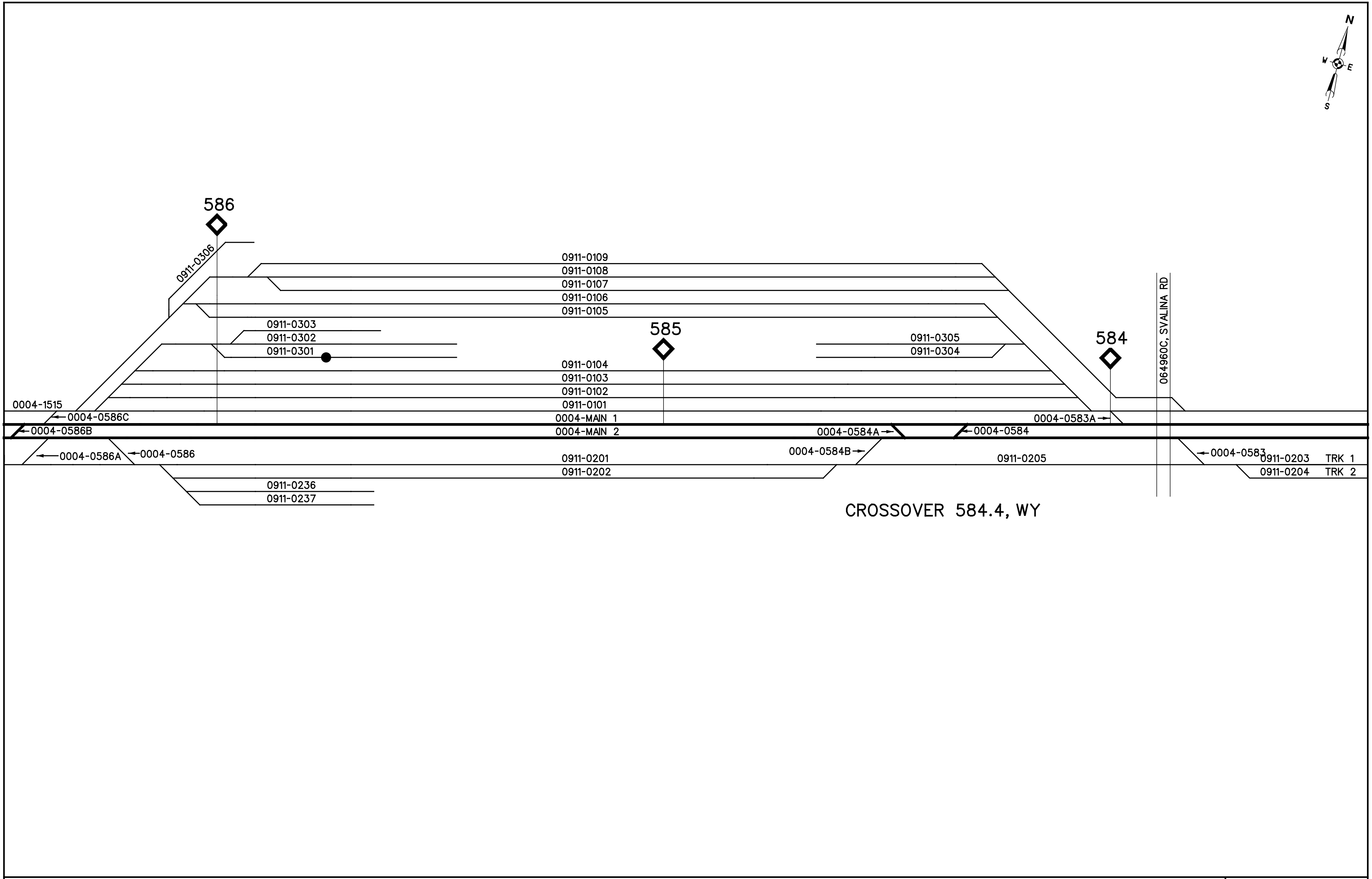
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018 Page 12 of 42

← West Gillette, WY

DONKEY CREEK, WY
Black Hills Subdivision

Edgemont, SD →



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JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

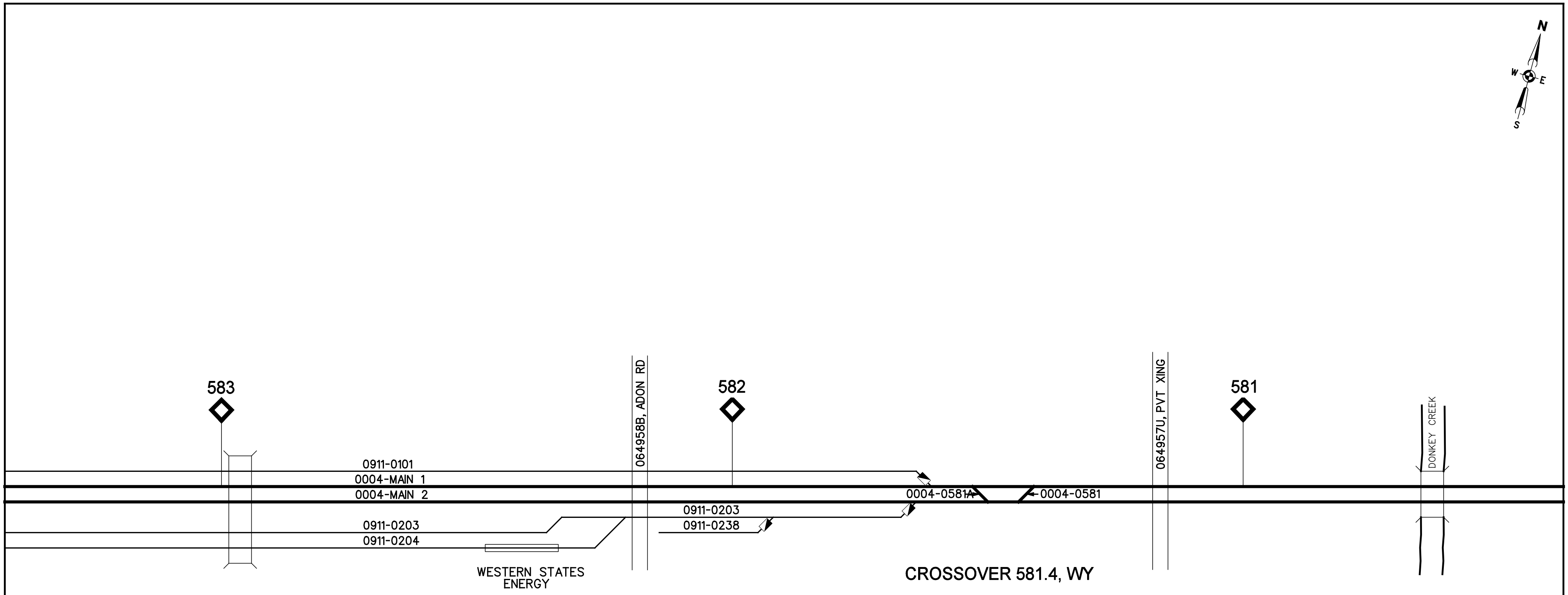
STATION ABBR: DONCRE
FSAC: 30581
REVISED: 3/23/2017
TEAM: DONK01011.DGN
TRK CHT: BLK013.DGN
TEAM PG 011

DONKEY CREEK, WY

Black Hills Subdivision

◄— West Gillete, WY

Edgemont, SD —►



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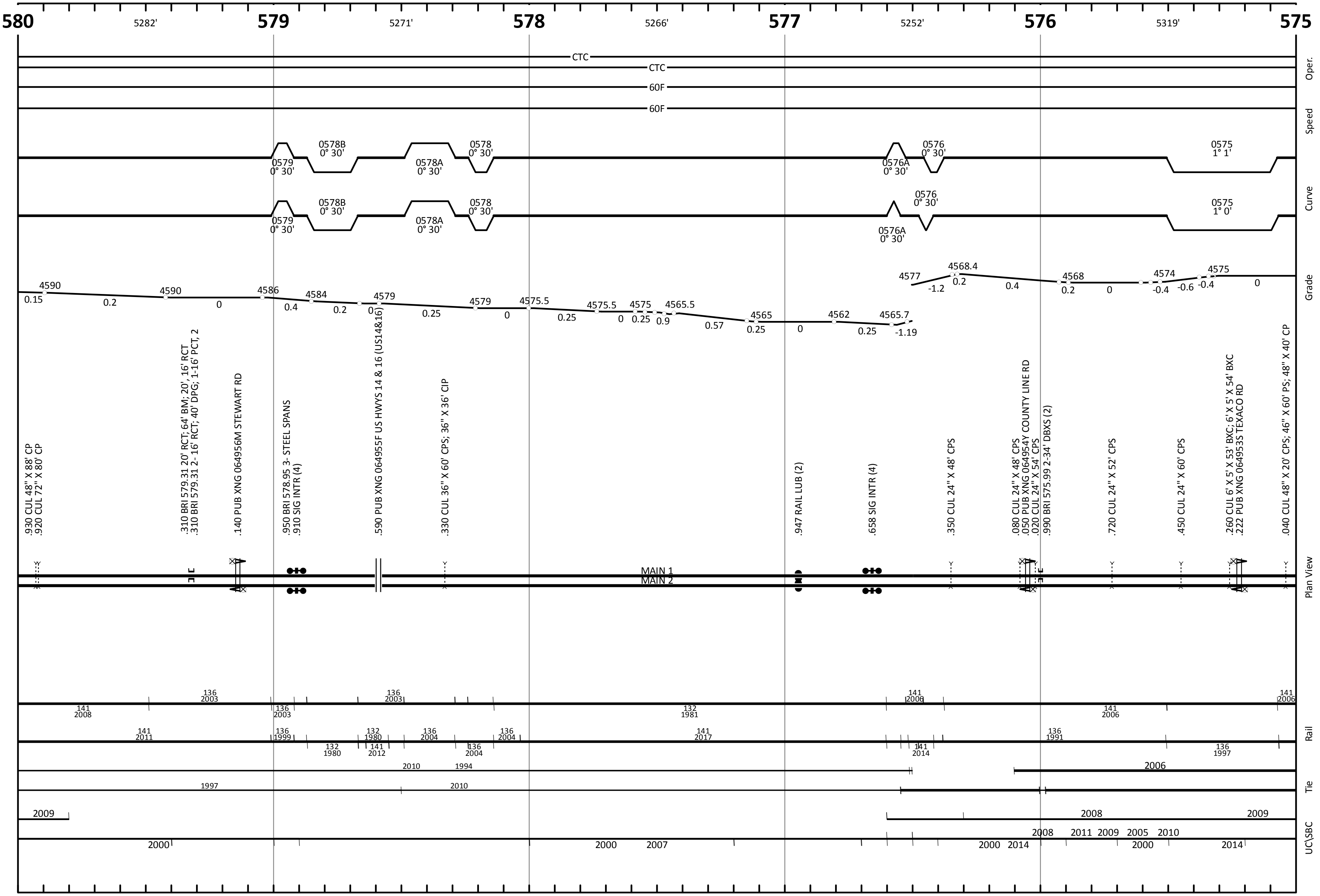
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: DONCRE
FSAC: 30581
REVISED: 11/4/2014
TEAM: DONK01013.DGN
TRK CHT: BLK014.DGN

◄ (WB) West Gillette, WY | Line Segment 4 | Edgemont, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

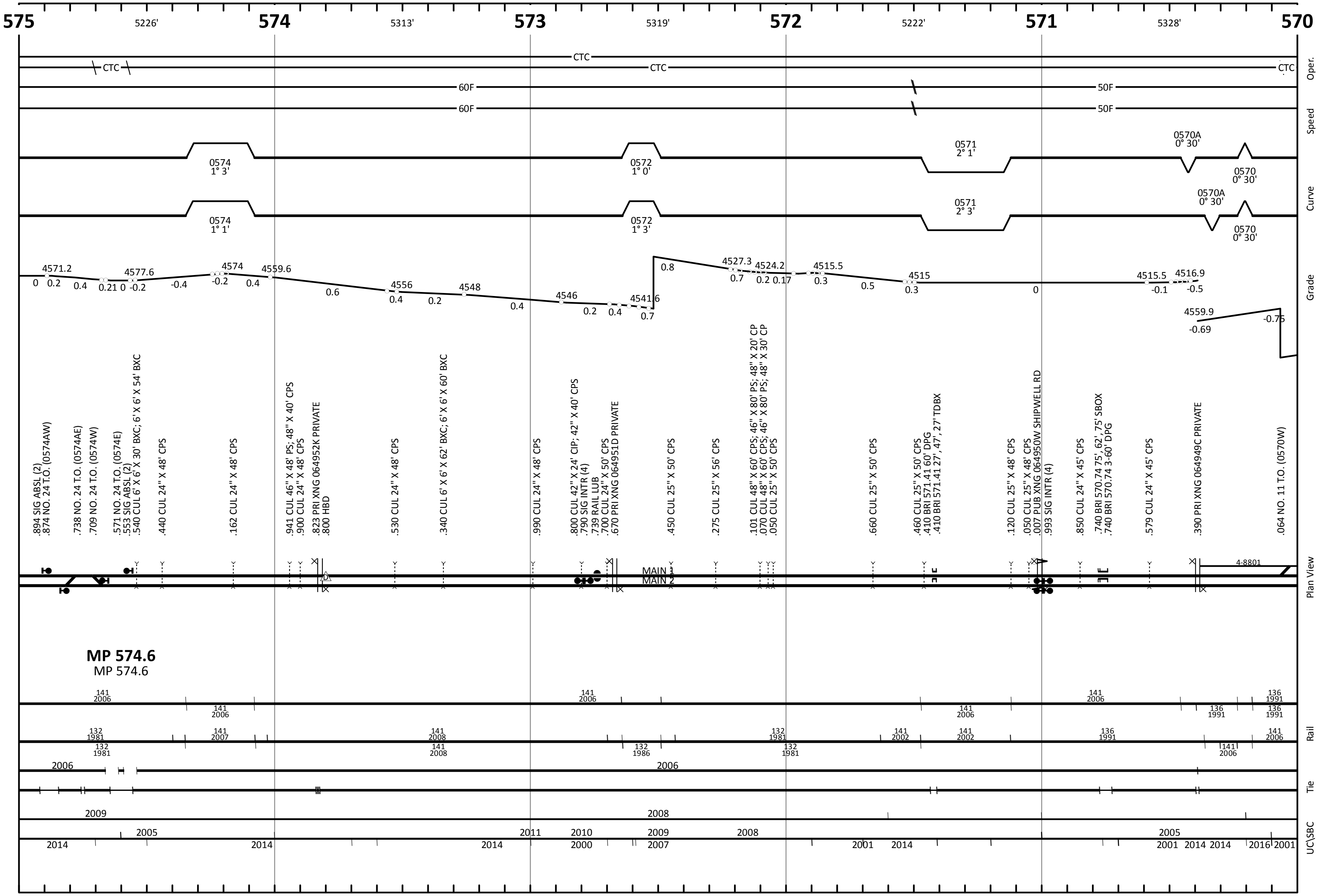
Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

◄ (WB) West Gillette, WY   Line Segment 4   Edgemont, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

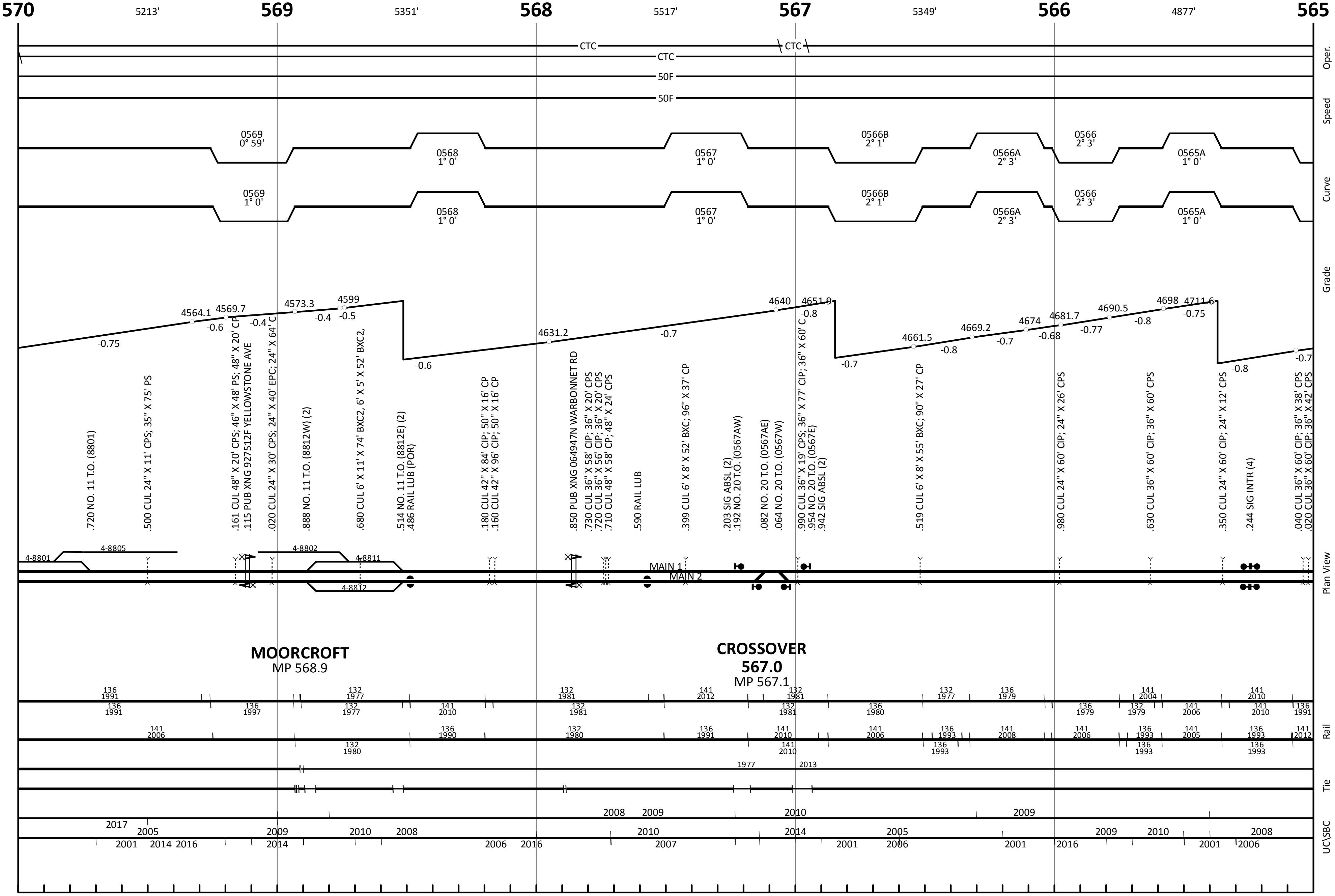
Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018

◄ (WB) West Gillette, WY Line Segment 4 Edgemont, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

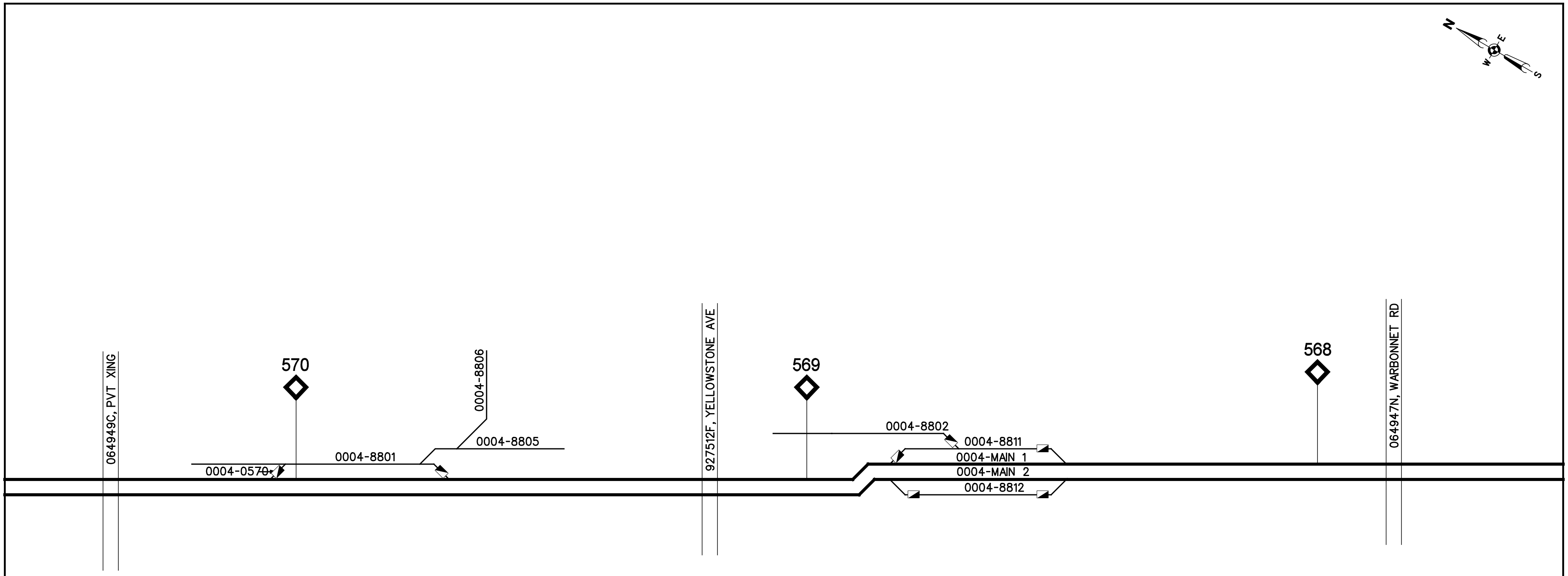
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018

← West Gillette, WY

MOORCROFT, WY
Black Hills Subdivision

Edgemont, SD →



BNSF RAILWAY

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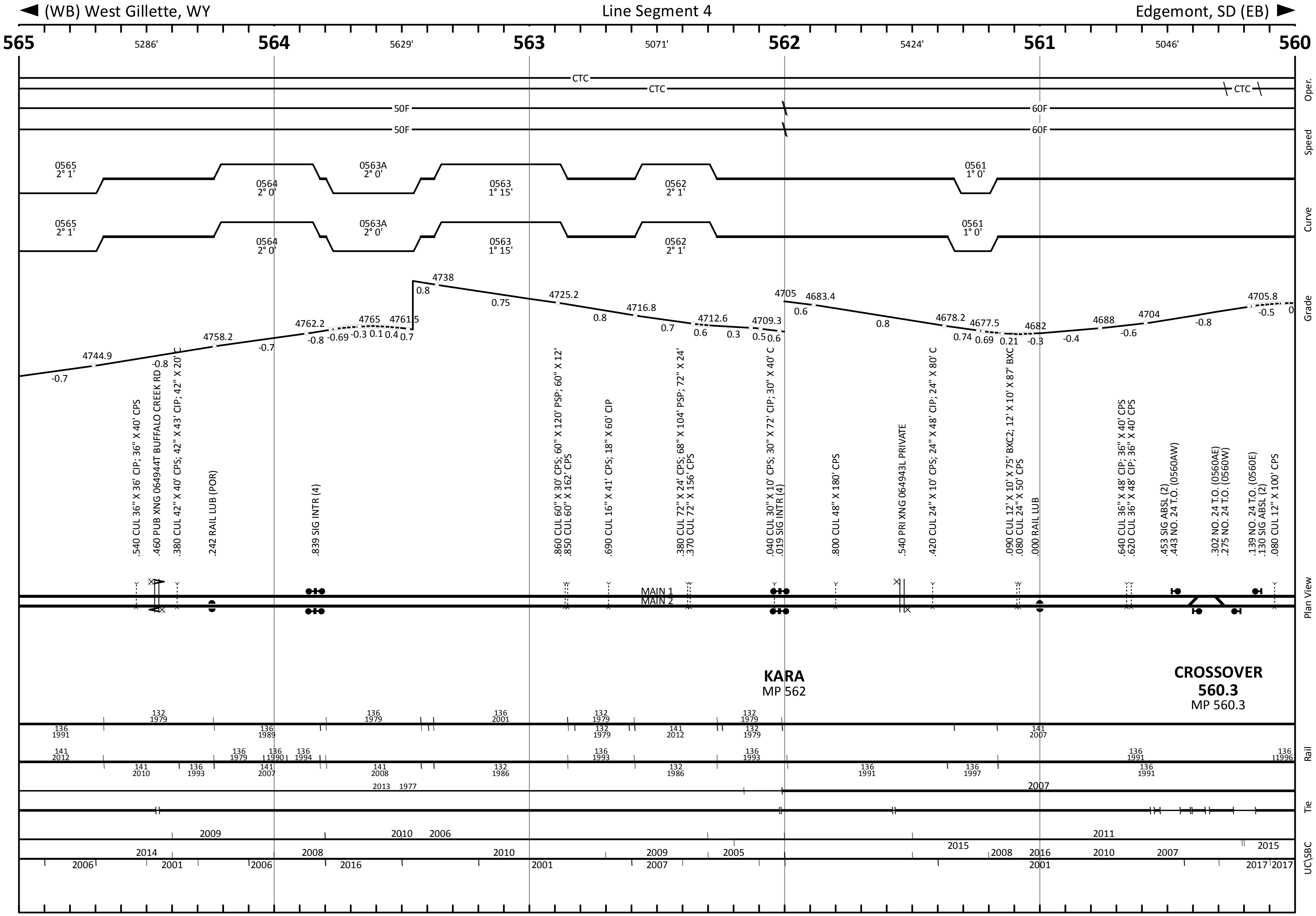
BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: MOORCR
FSAC: 30568
REVISED: 11/4/2014
TEAM: MOOR88015.DGN
TRK CHT: BLK018.DGN
TEAM PG 015



Black Hills Subdivision

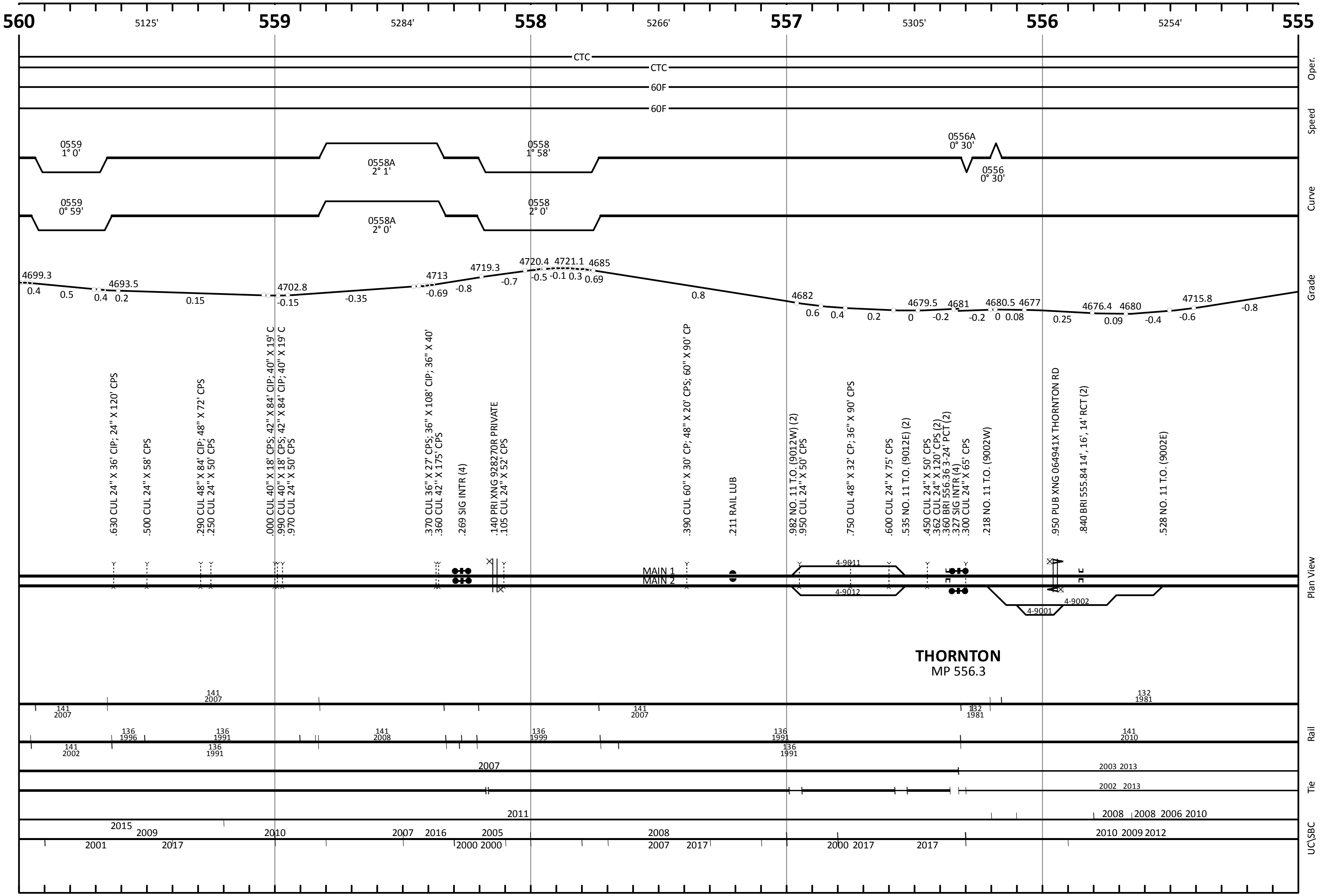
Powder River Operating Division
Powder River West Engineering Division

BNSF RAILWAY
System Maintenance and Planning

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018

◀ (WB) West Gillette, WY Line Segment 4 Edgemont, SD (EB) ▶



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

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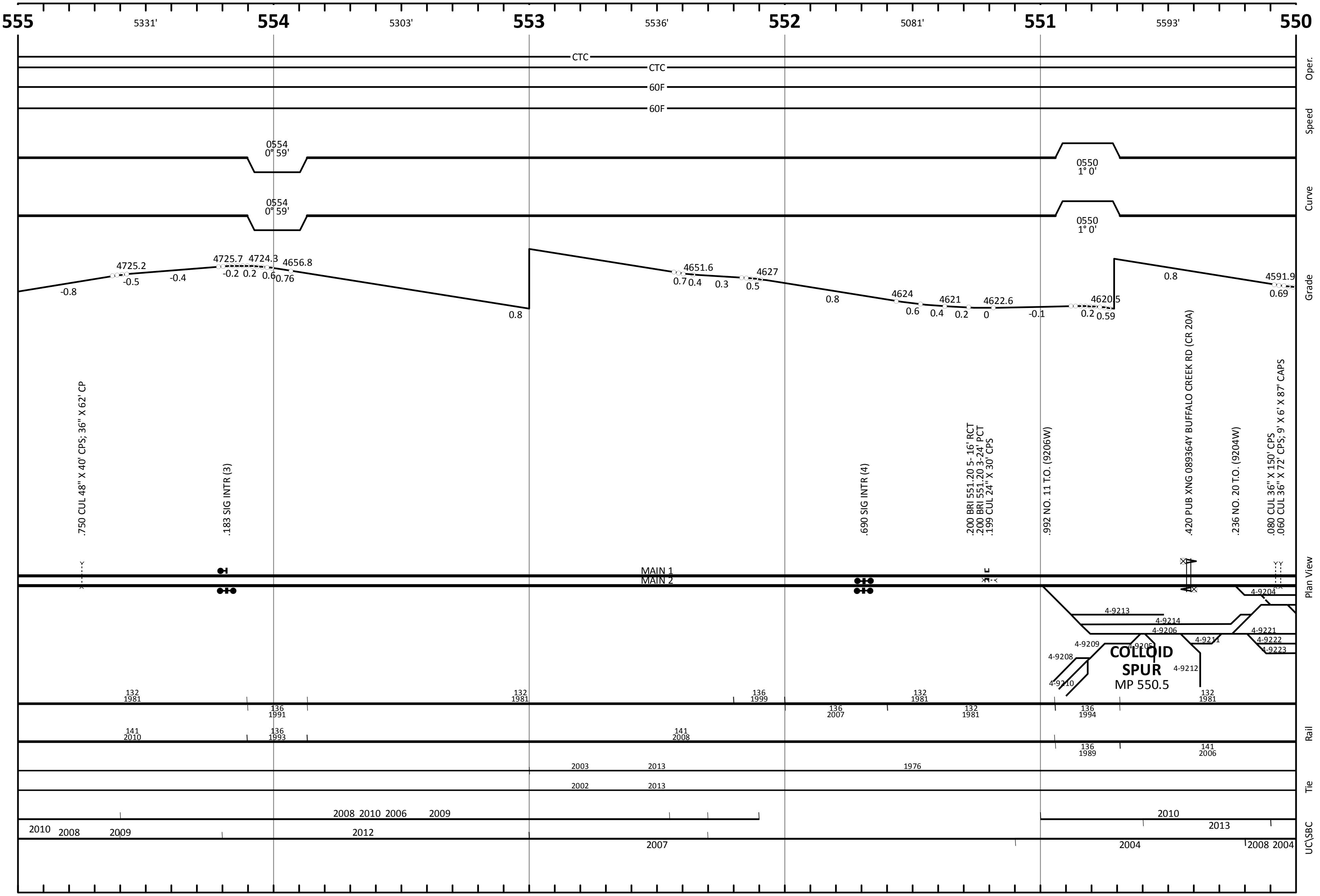


BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

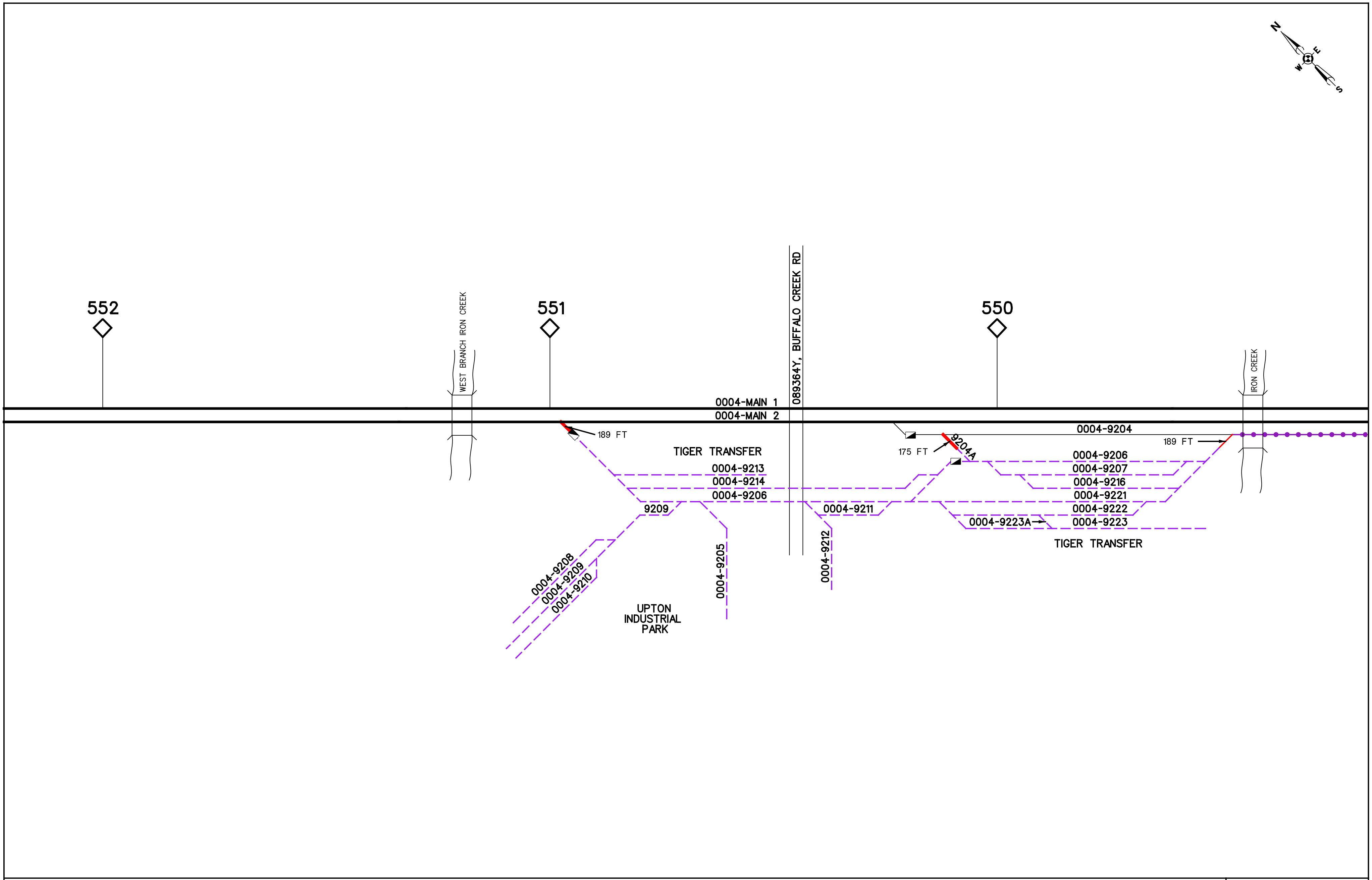
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018 Page 21 of 42

UPTON, WY
Black Hills Subdivision

← West Gillette, WY

Edgemont, SD →



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IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

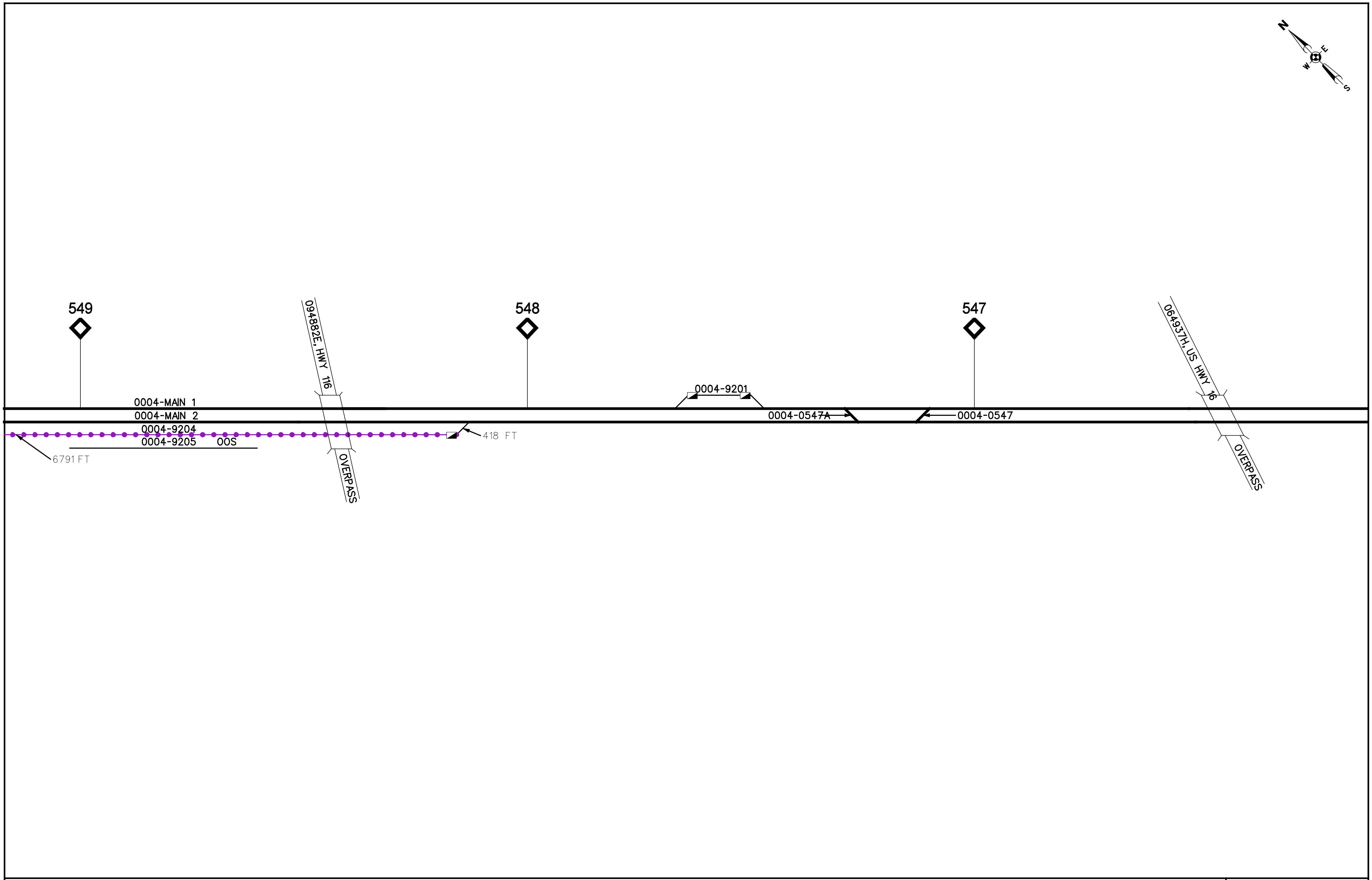
STATION ABBR: UPTON
FSAC: 57740
REVISED: 4/24/2018
TEAM: UPTO92019.DGN
TRK CHT: BLK022.DGN
TEAM PG 019

UPTON, WY

Black Hills Subdivision

← West Gillette, WY

Edgemont, SD →



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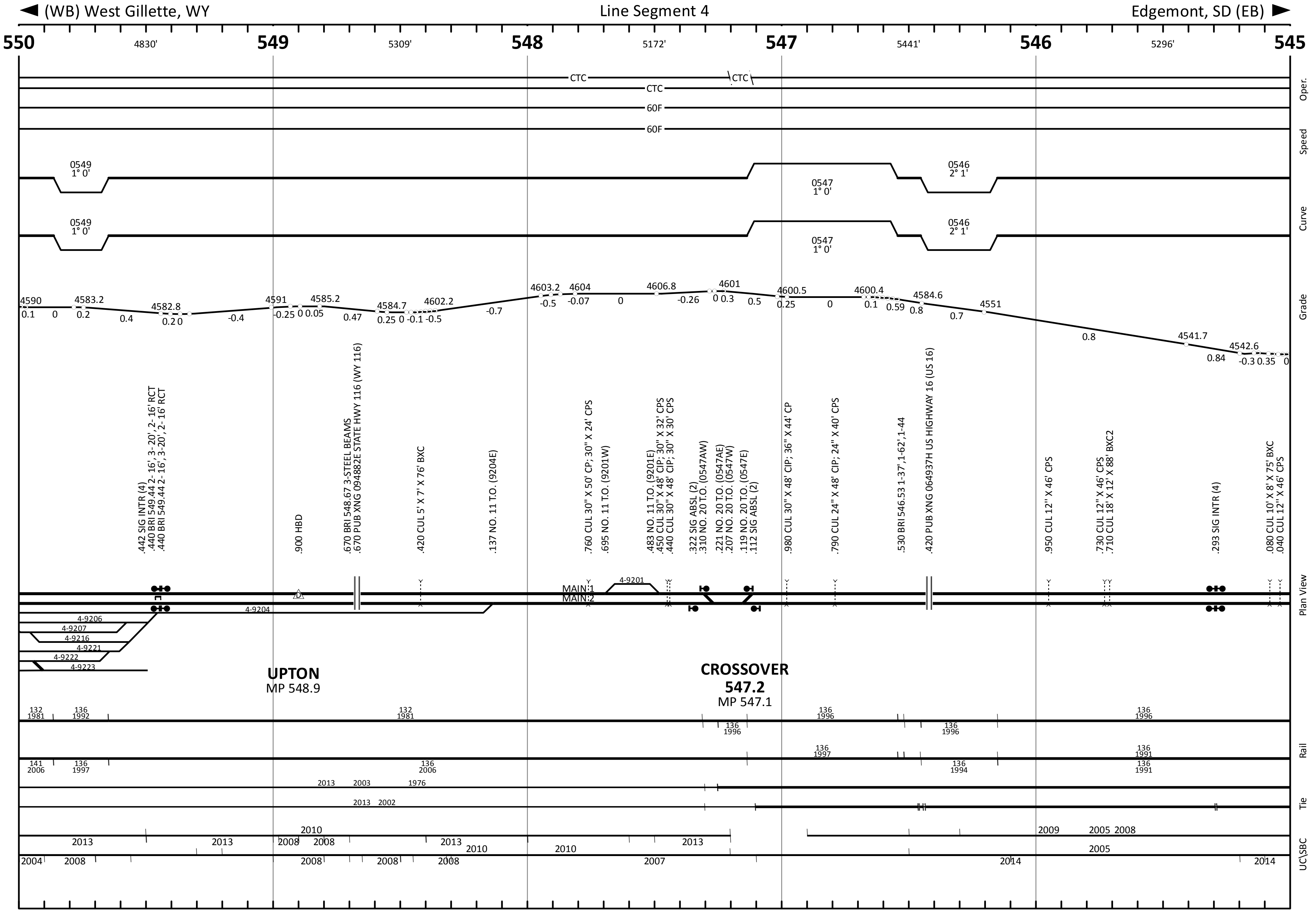
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: UPTON
FSAC: 57740
REVISED: 11/4/2014
TEAM: UPT092021.DGN
TRK CHT: BLK023.DGN



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

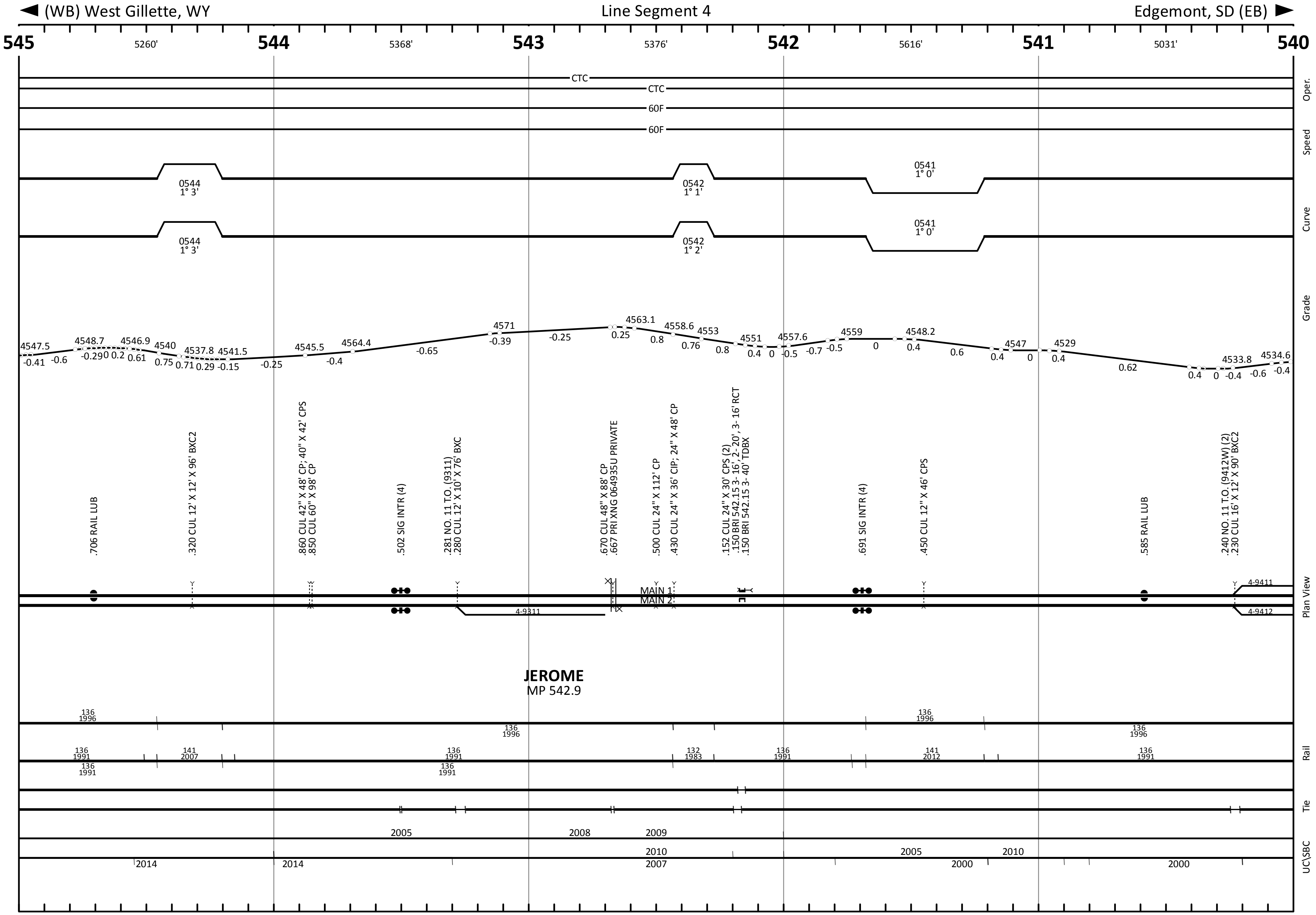
Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018

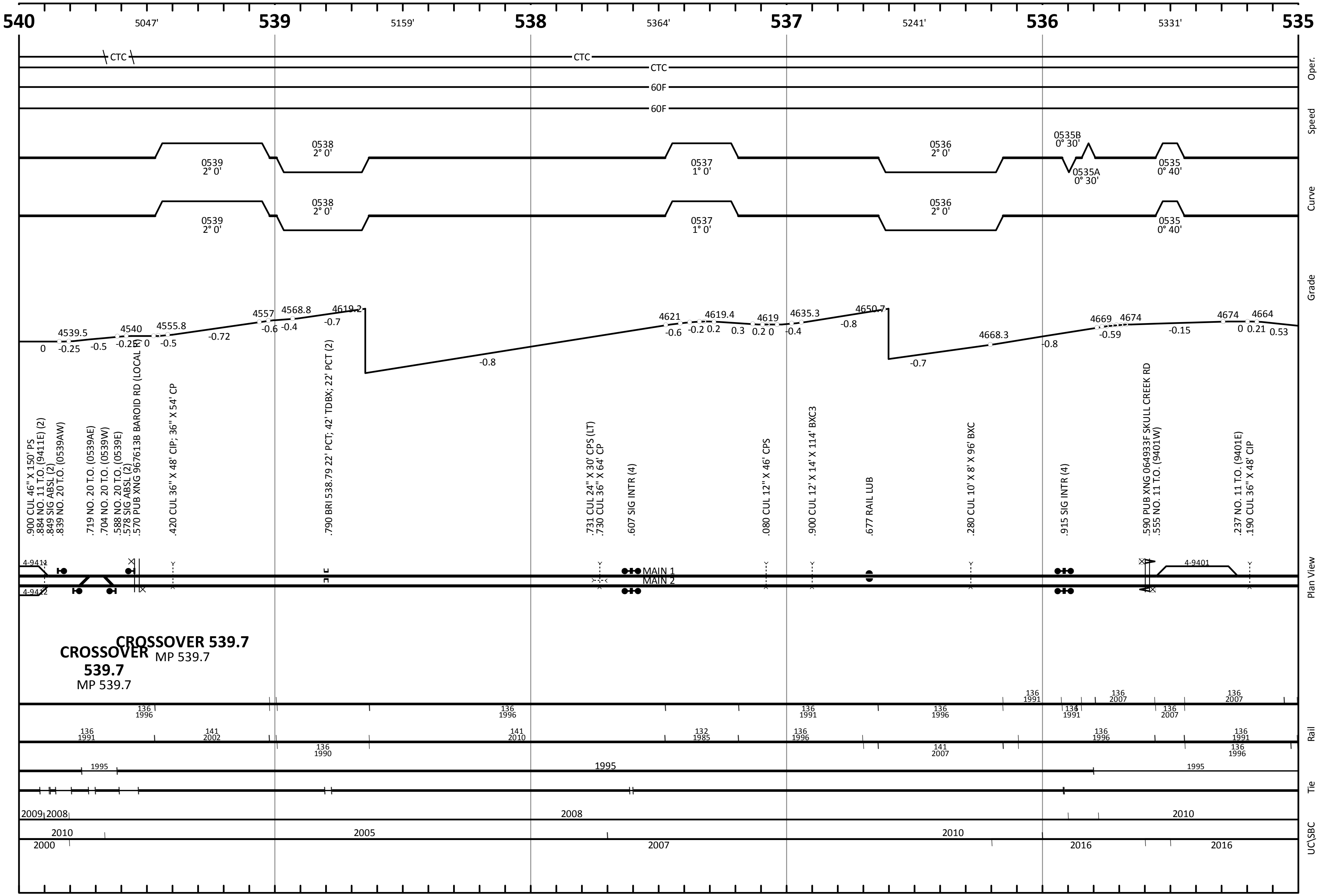


BNSF RAILWAY
System Maintenance and Planning

Black Hills Subdivision
Powder River Operating Division
Powder River West Engineering Division

Engineering Track Chart
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018 Page 25 of 42

◄ (WB) West Gillette, WY — Line Segment 4 — Edgemont, SD (EB) ►



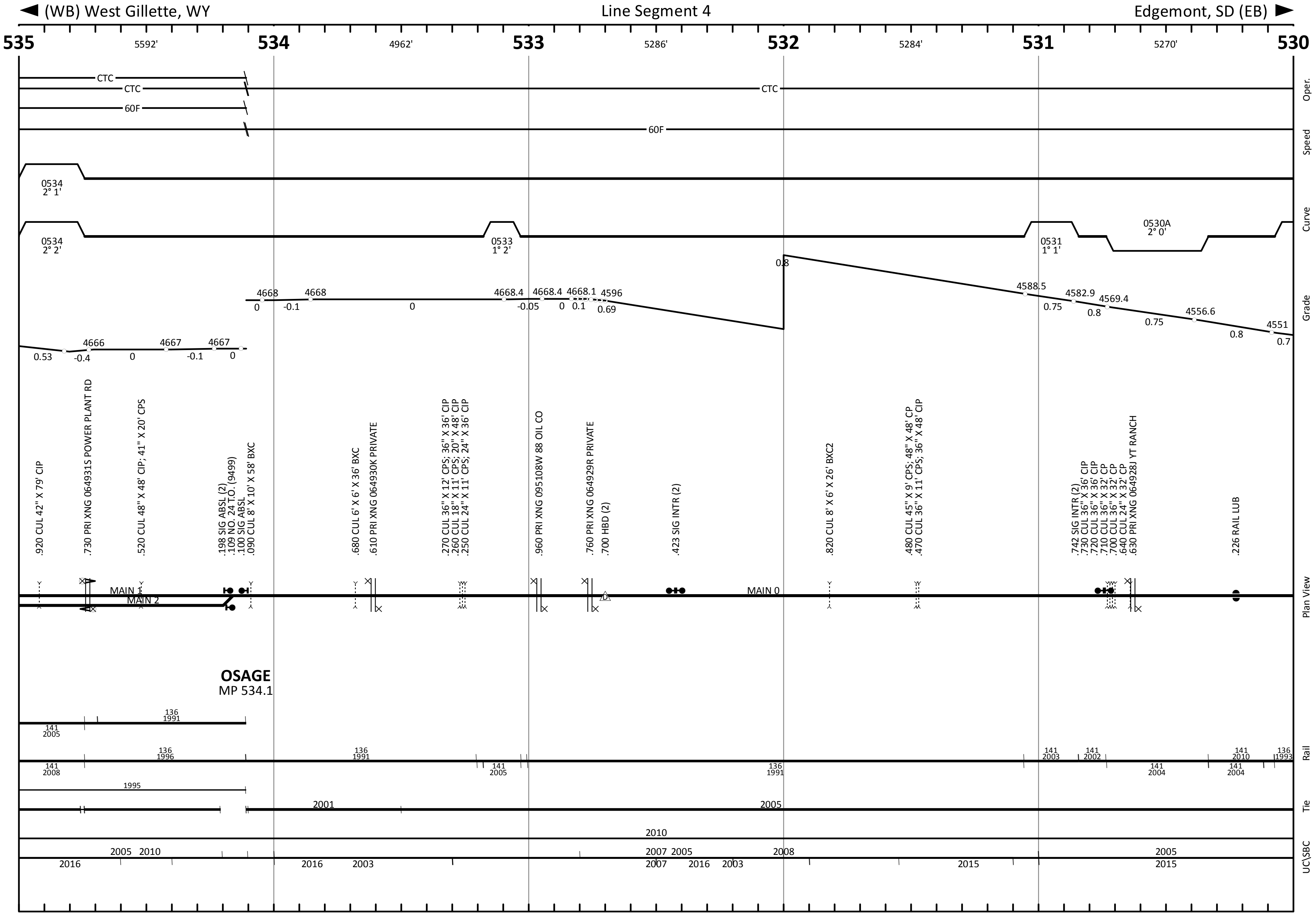
System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018 Page 26 of 42



RAILWAY

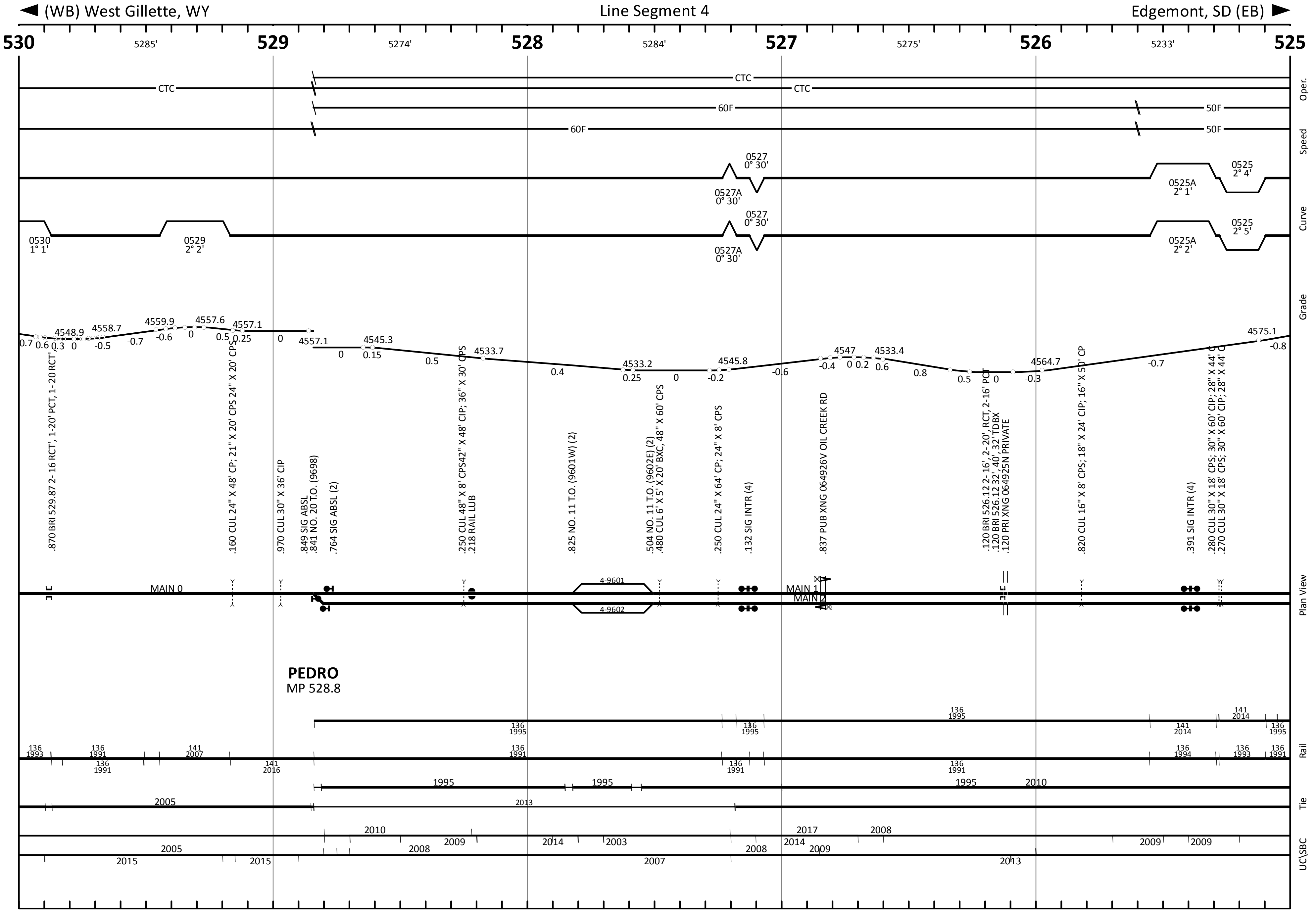
System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018 Page 27 of 42



System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
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Engineering Track Chart

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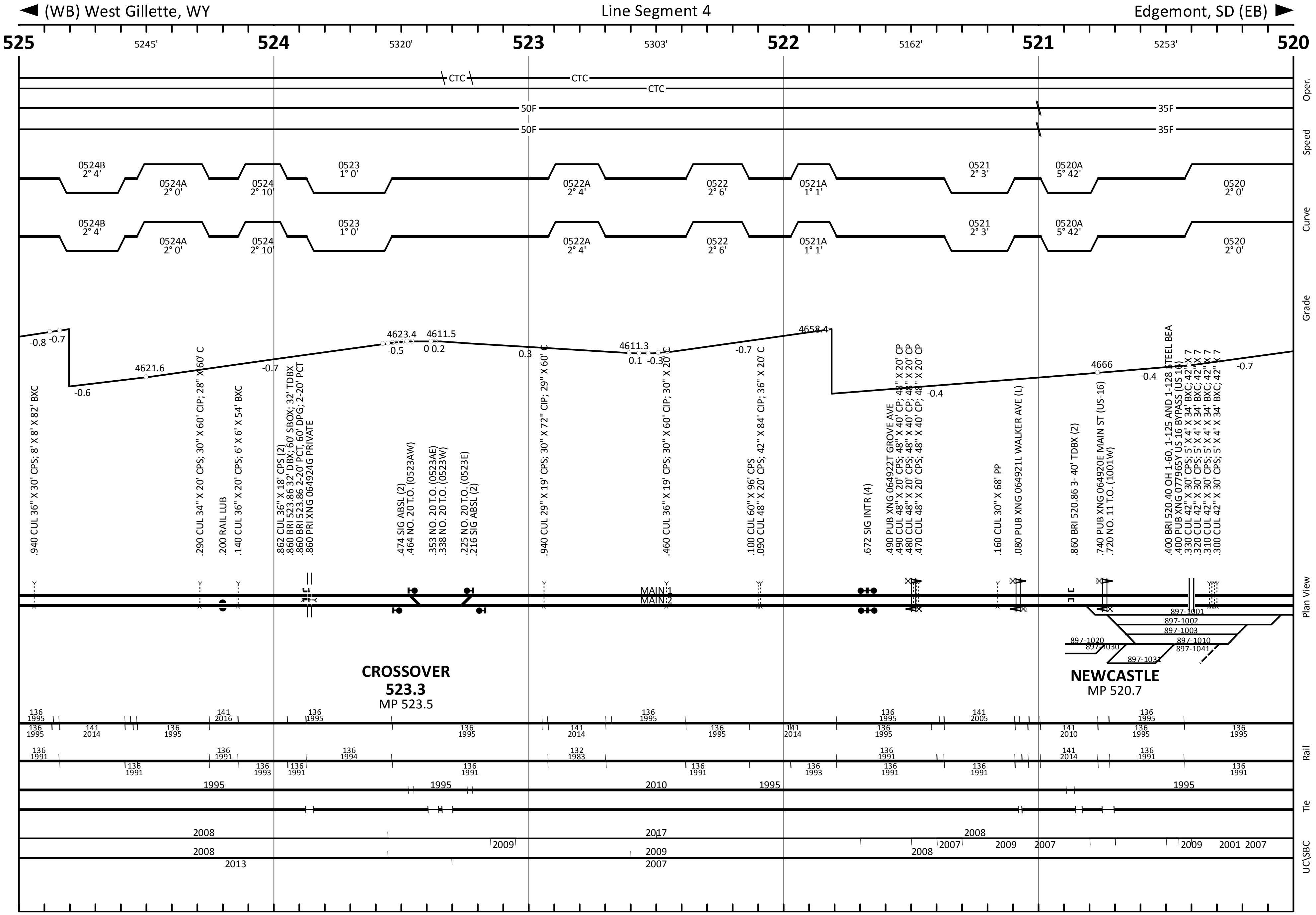
Revised to July 11, 2018



Black Hills Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018

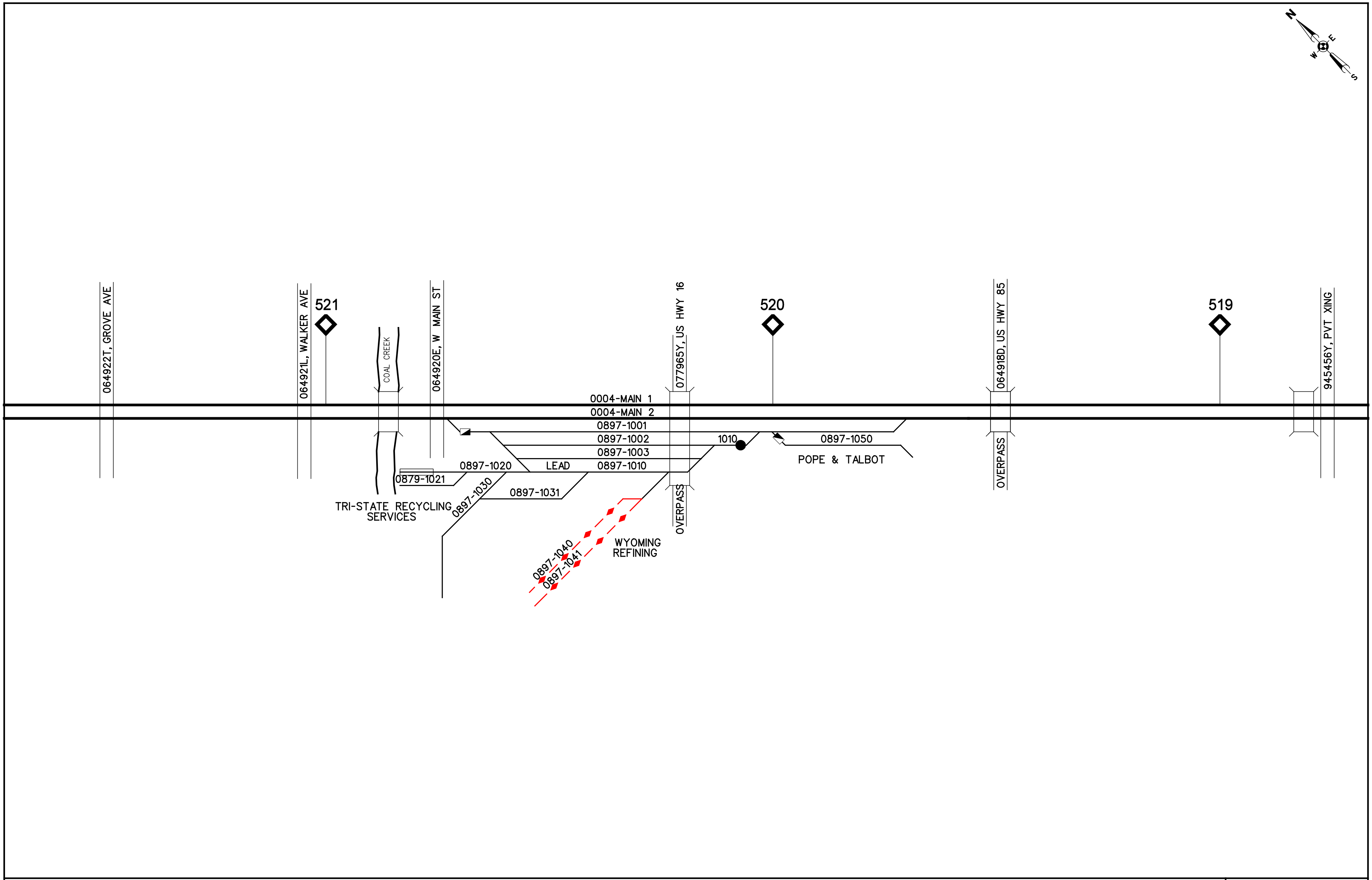
BNSF RAILWAY

System Maintenance and Planning

NEWCASTLE, WY
Black Hills Subdivision

← West Gillete, WY

Edgemont, SD →



RAILWAY

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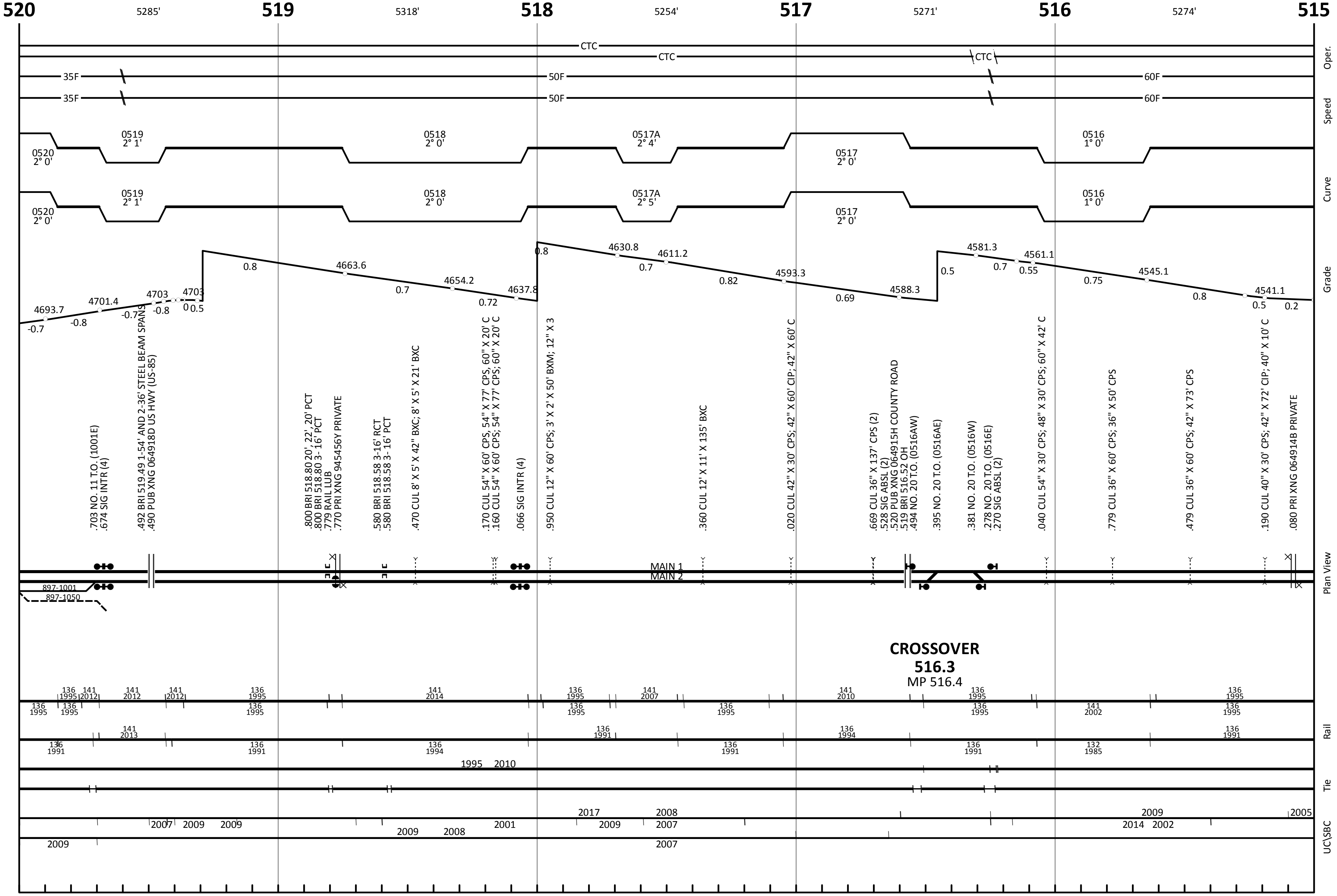
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: NEWCWY
FSAC: 30519
REVISED: 11/4/2014
TEAM: NEWC10031.DGN
TRK CHT: BLK030.DGN

◄ (WB) West Gillette, WY

Line Segment 4

Edgemont, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

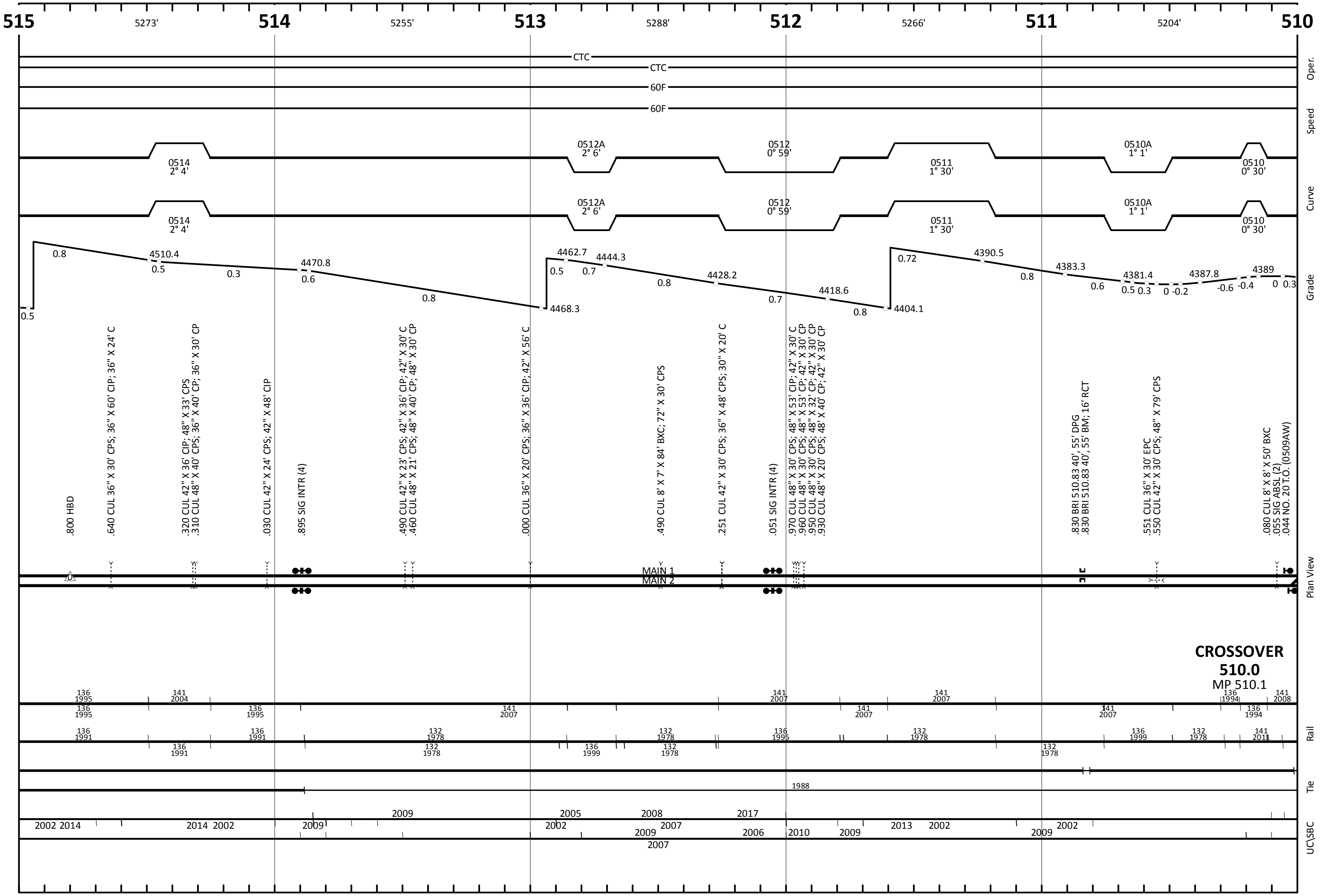
Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

◄ (WB) West Gillette, WY Line Segment 4 Edgemont, SD (EB) ►



BNSF RAILWAY
System Maintenance and Planning

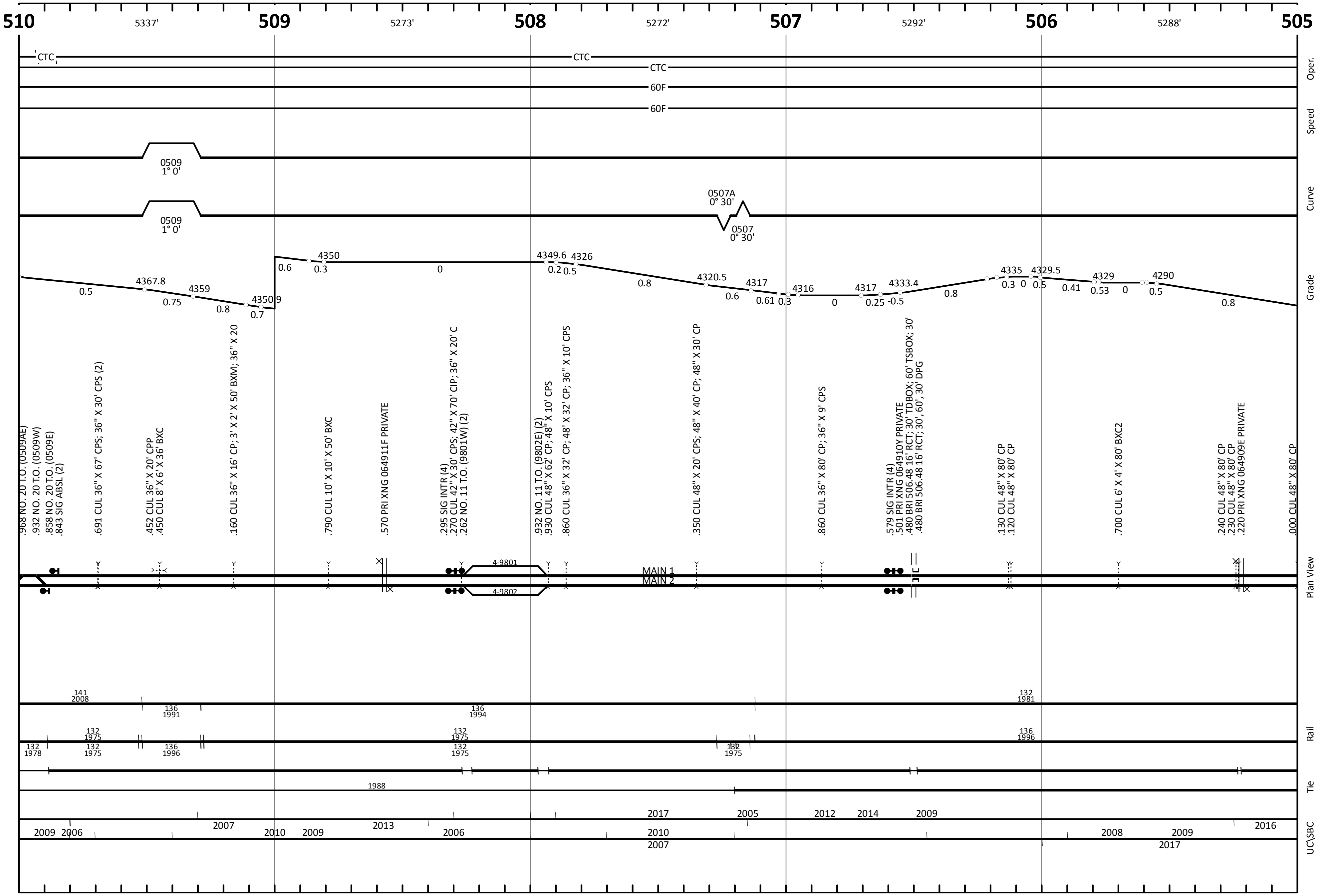
Black Hills Subdivision
Powder River Operating Division
Powder River West Engineering Division

Engineering Track Chart
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018

◄ (WB) West Gillette, WY

Line Segment 4

Edgemont, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

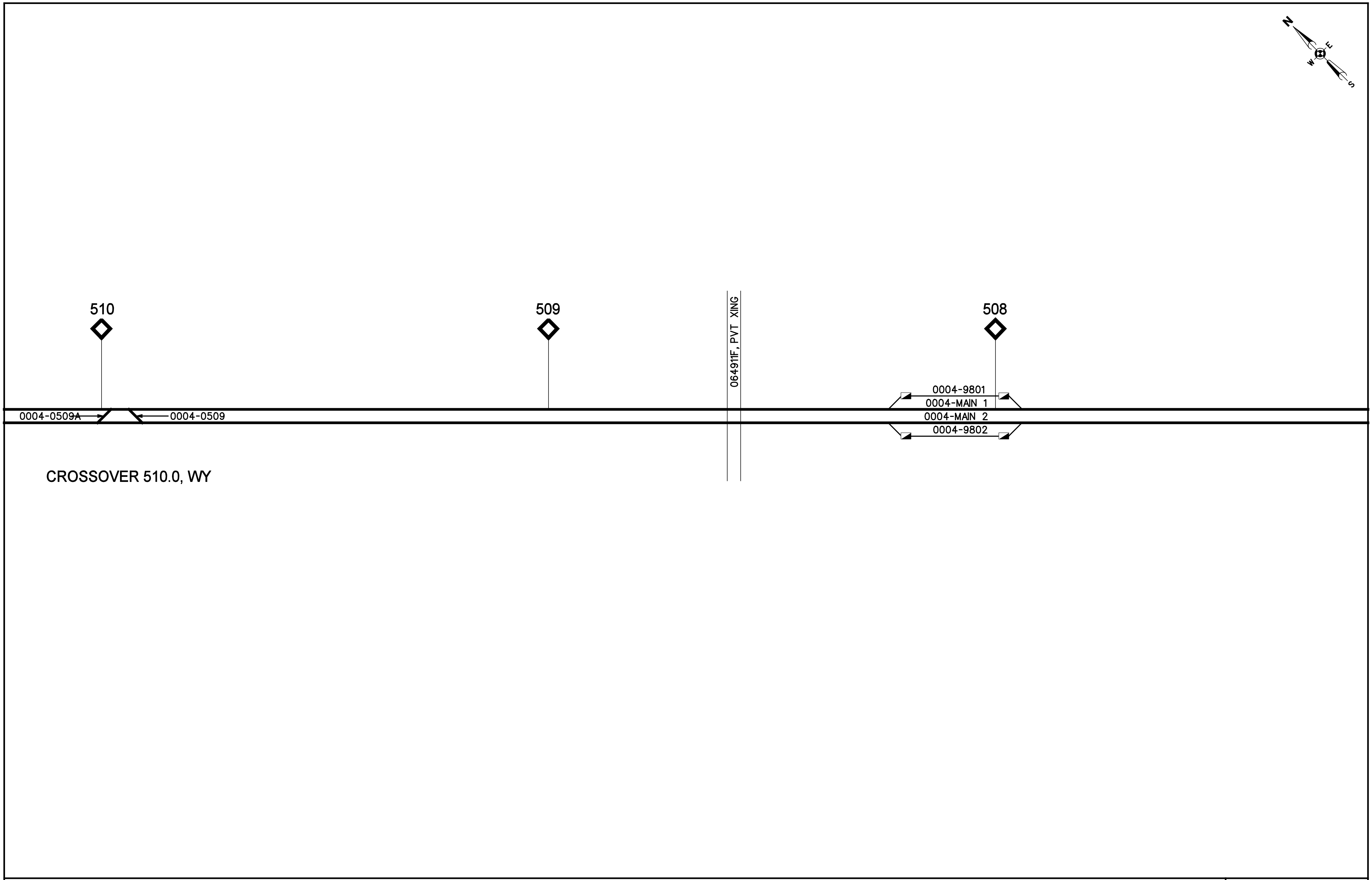
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 11, 2018

← West Gillette, WY

OWENS, WY
Black Hills Subdivision

Edgemont, SD →



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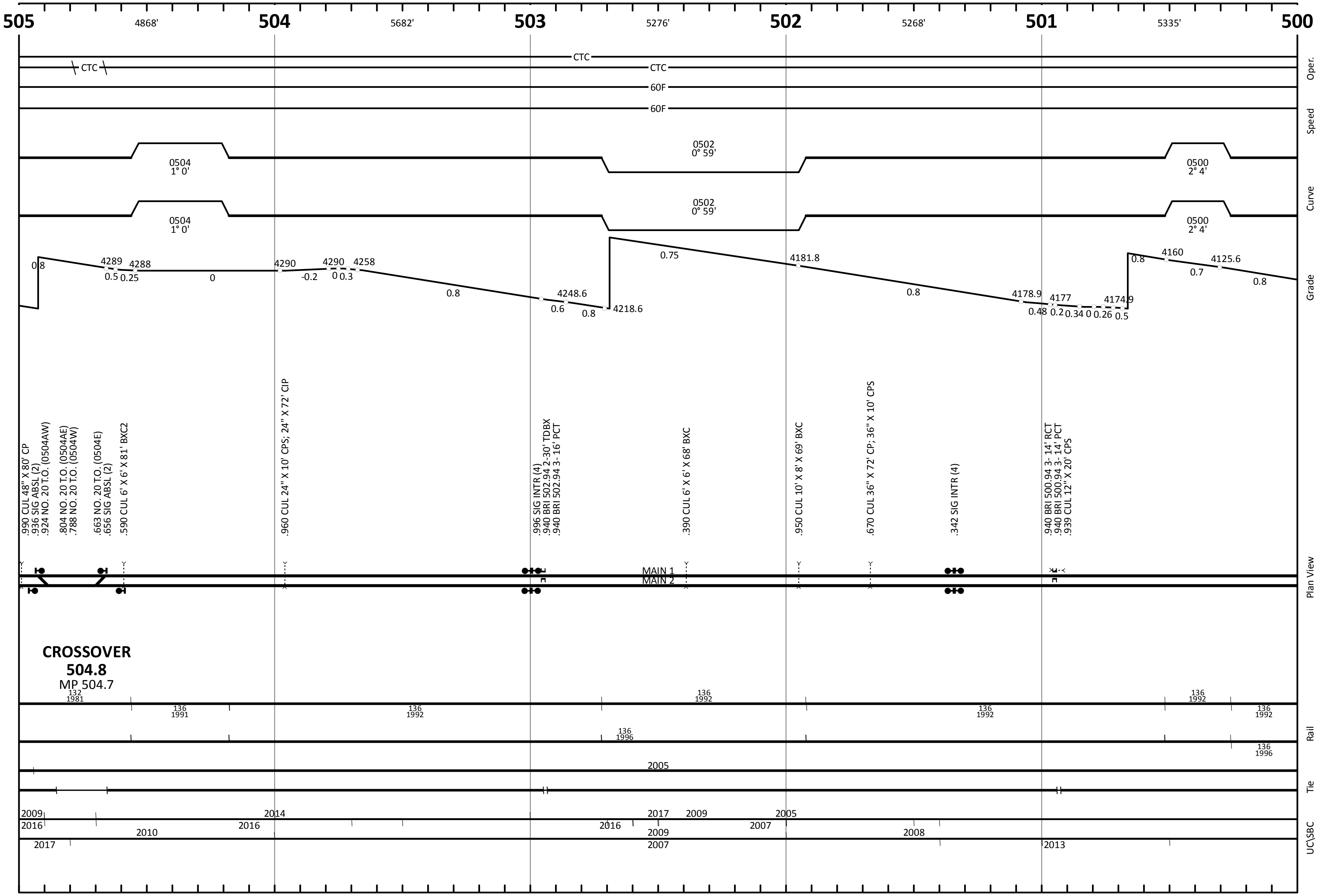
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: OWENS
FSAC: *****
REVISED: 11/4/2014
TEAM: OWEN98033.DGN
TRK CHT: BLK034.DGN
TEAM PG 033

◄ (WB) West Gillette, WY Line Segment 4 Edgemont, SD (EB) ►



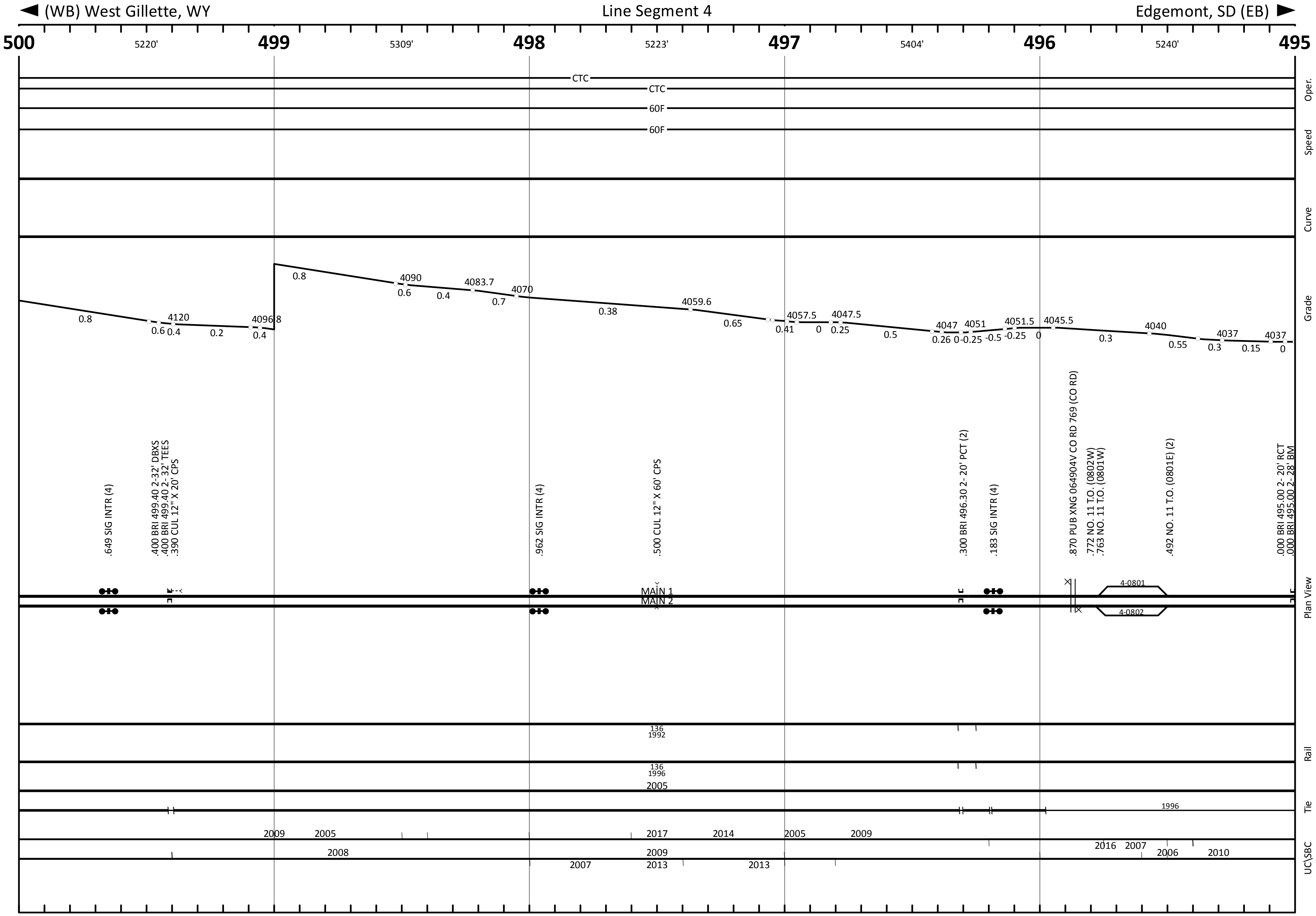
System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018



BNSF RAILWAY
System Maintenance and Planning

Black Hills Subdivision
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Powder River West Engineering Division

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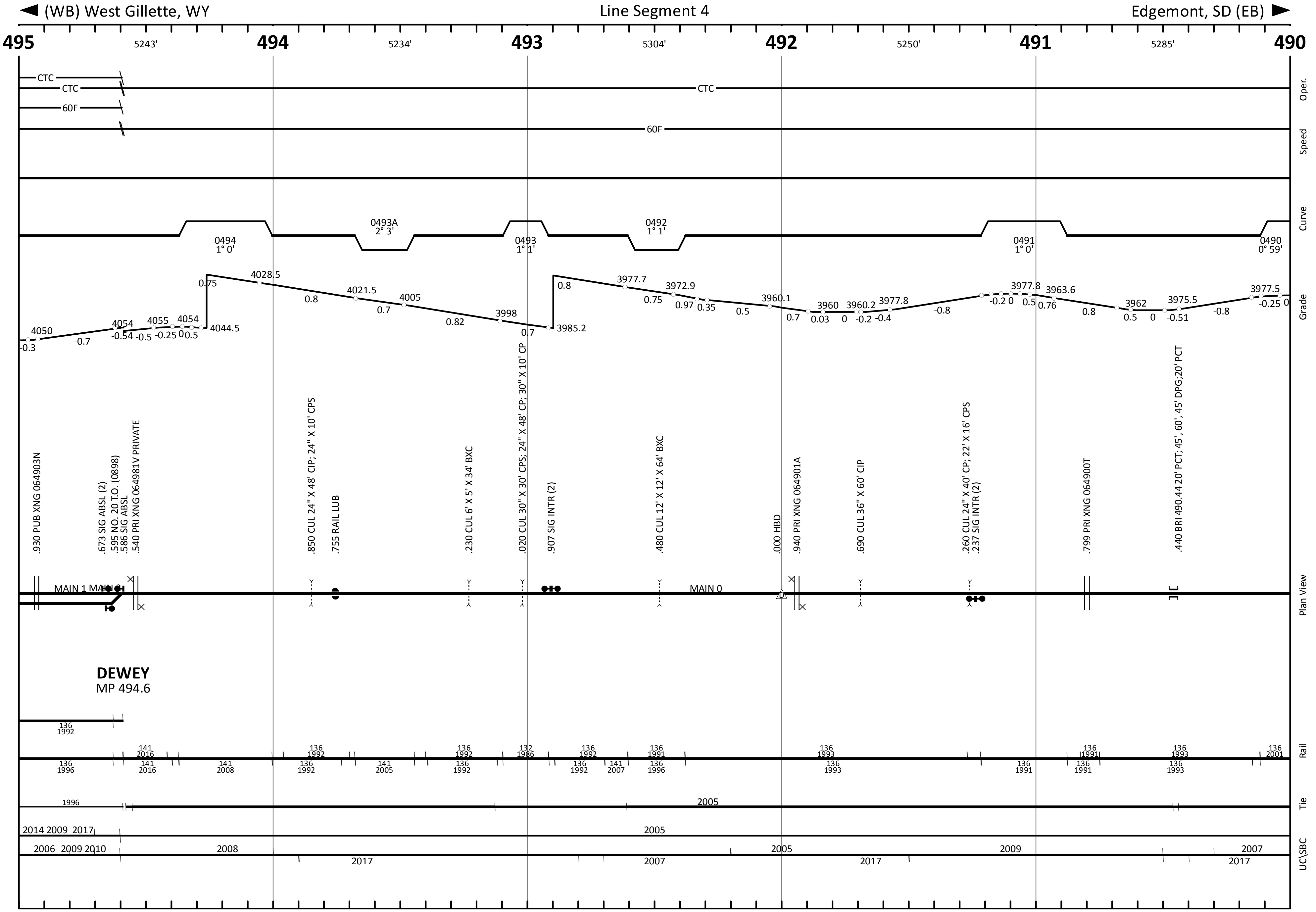
Revised to July 11, 2018



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System Maintenance and Planning

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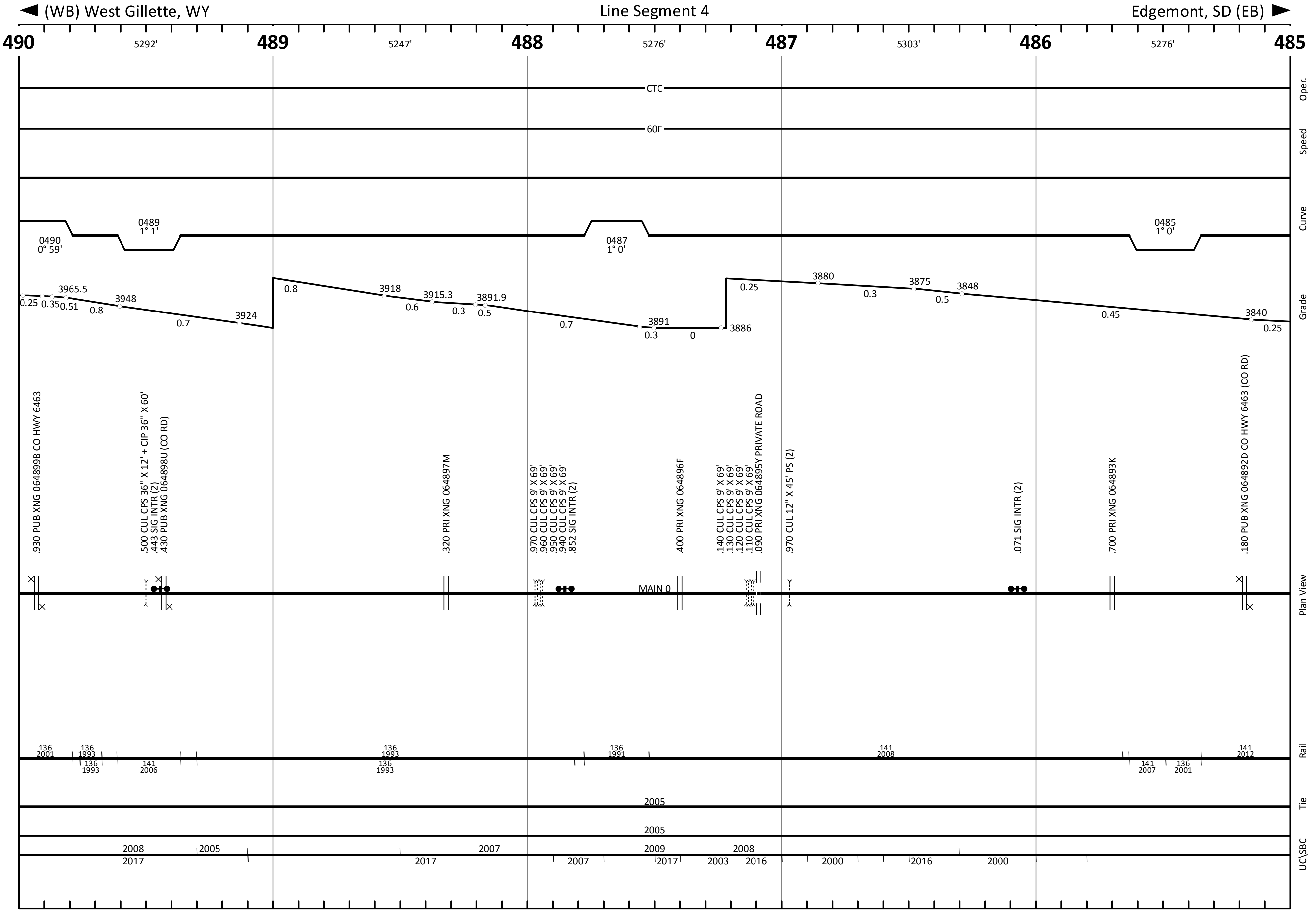

BNSF RAILWAY
System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
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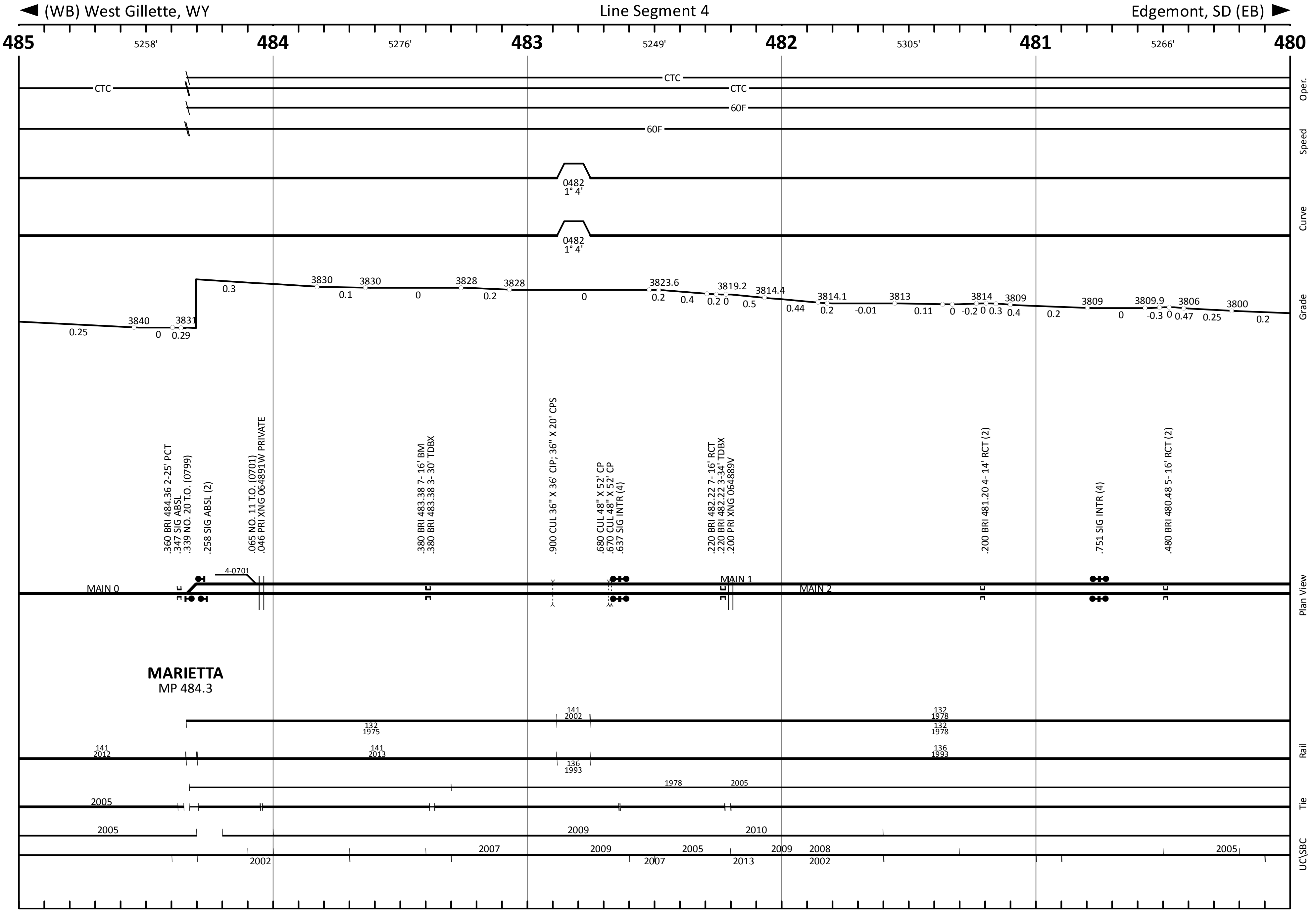
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018 Page 38 of 42



System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division
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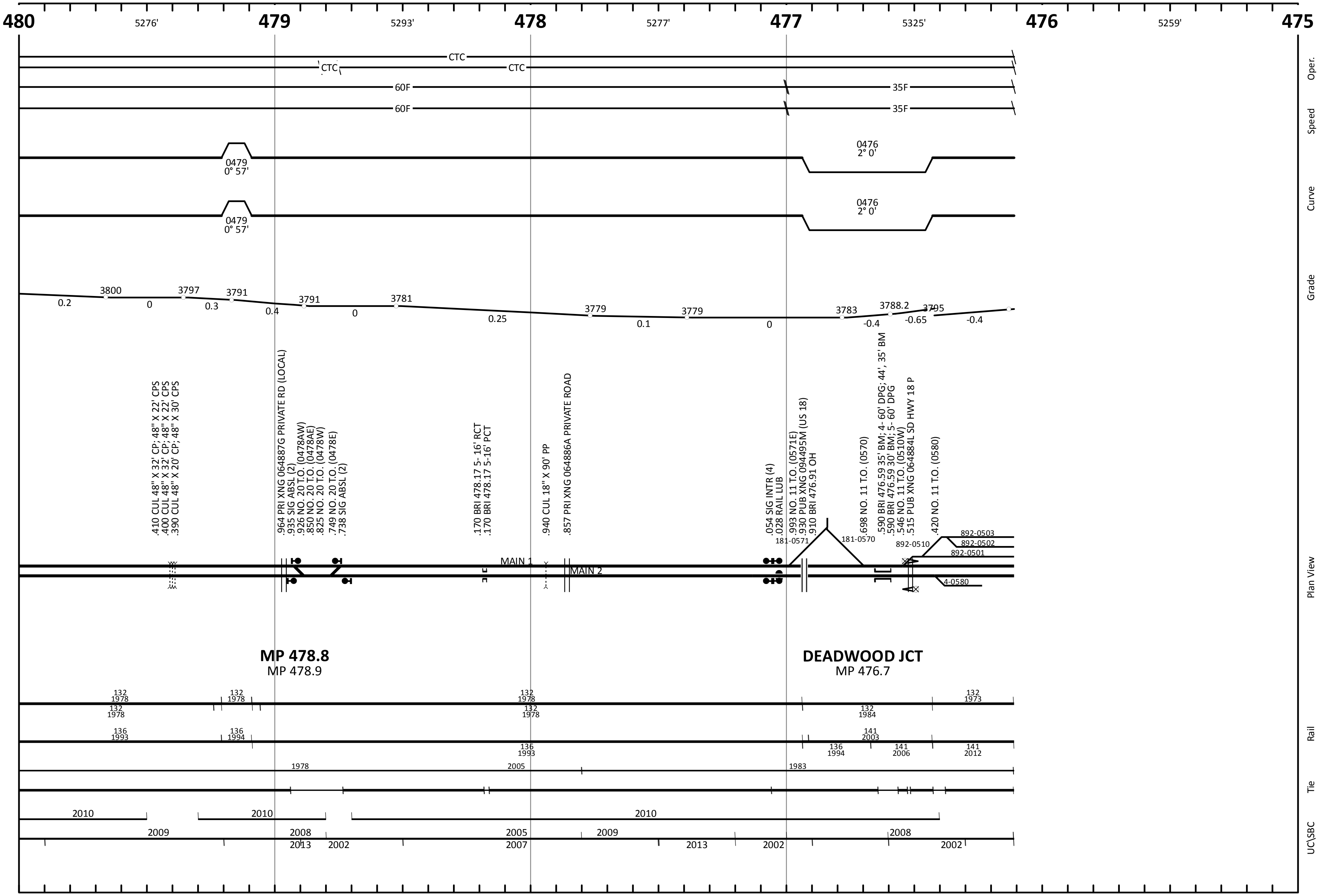
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 11, 2018 Page 39 of 42

◄ (WB) West Gillette, WY Line Segment 4 Edgemont, SD (EB) ►



System Maintenance and Planning

Black Hills Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

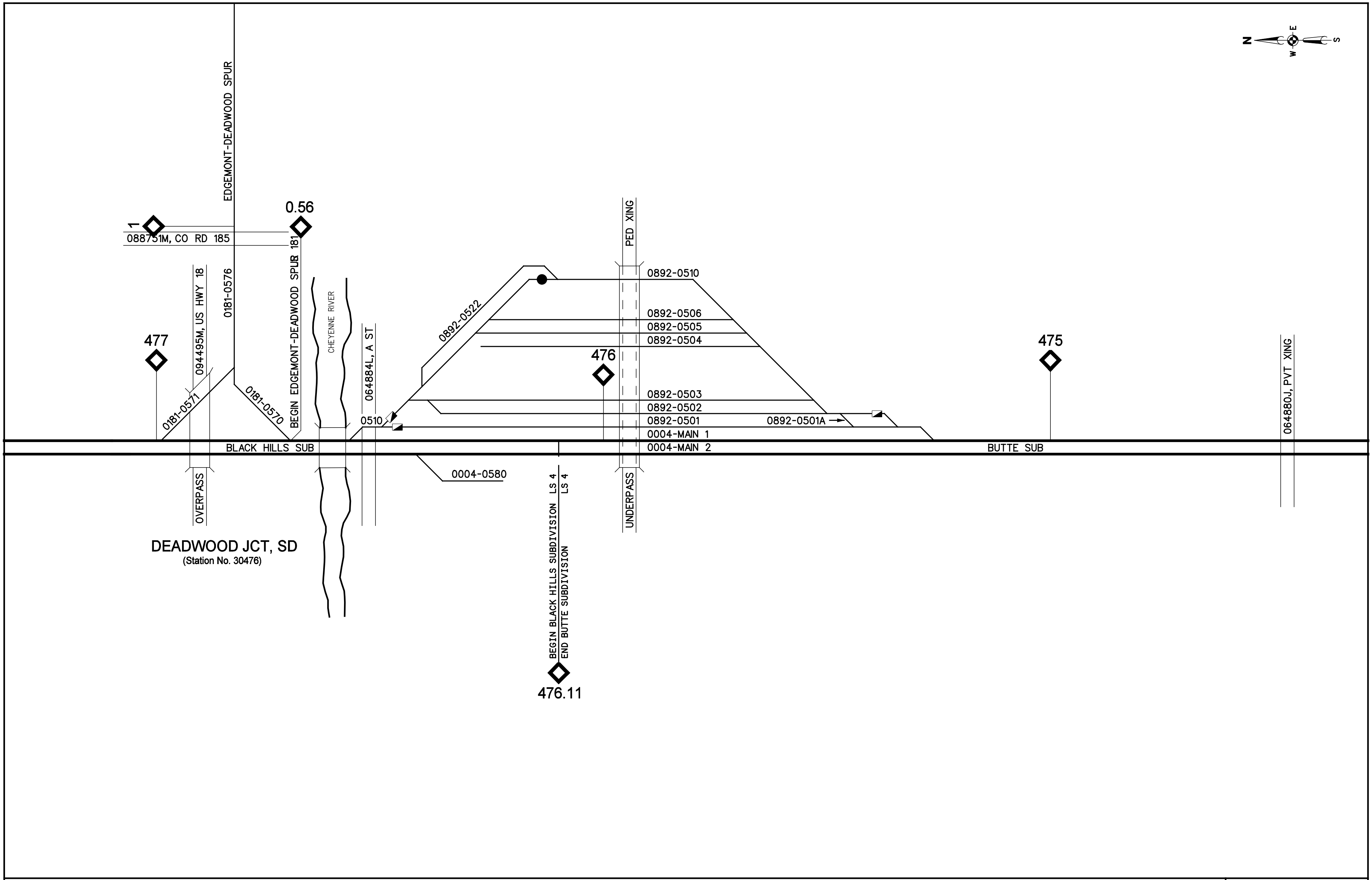
Revised to July 11, 2018

EDGEMONT, WY

Black Hills Subdivision

← West Gillete, WY

EAST ALLIANCE, NE →



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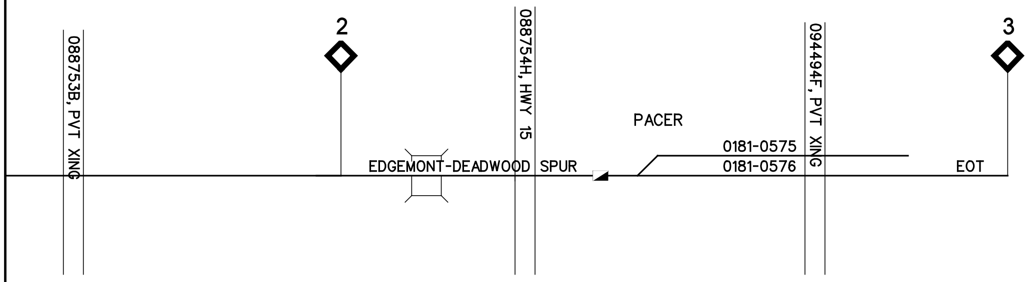
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: EDGEMO
FSAC: 30475
REVISED: 5/3/2016
TEAM: EDGE05039.DGN
TRK CHT: BLK025A.DGN

EDGEMONT, SD
Black Hills Subdivision



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STATION ABBR: EDGEMO
FSAC: 30475
REVISED: 11/4/2014
TEAM: EDGE05041.DGN
TRK CHT: BLK042.DGN
TEAM PG 041

Track Chart
Butte Subdivision

East Alliance, NE to Edgemont, SD

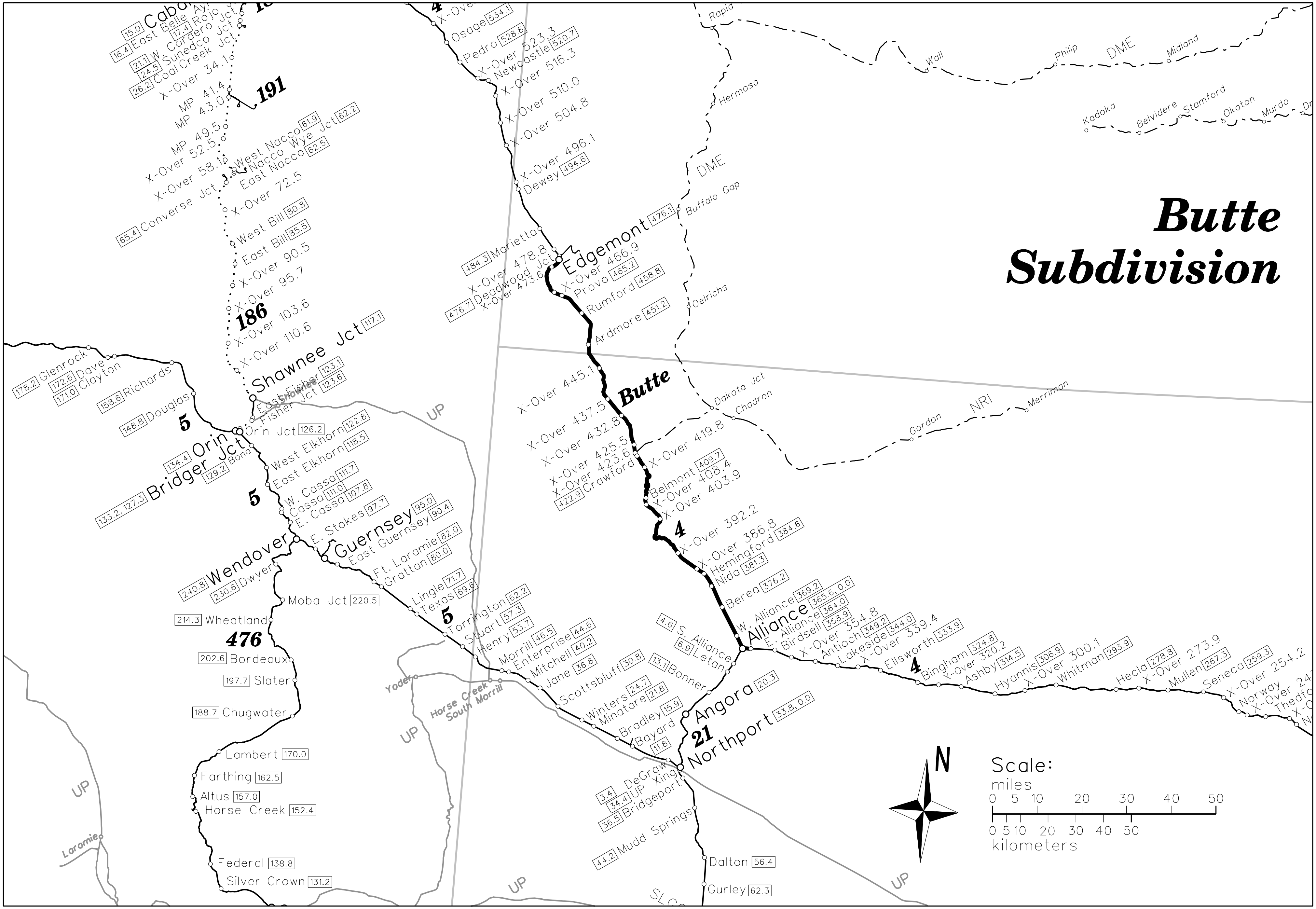
MP 364.11 to MP 476.11

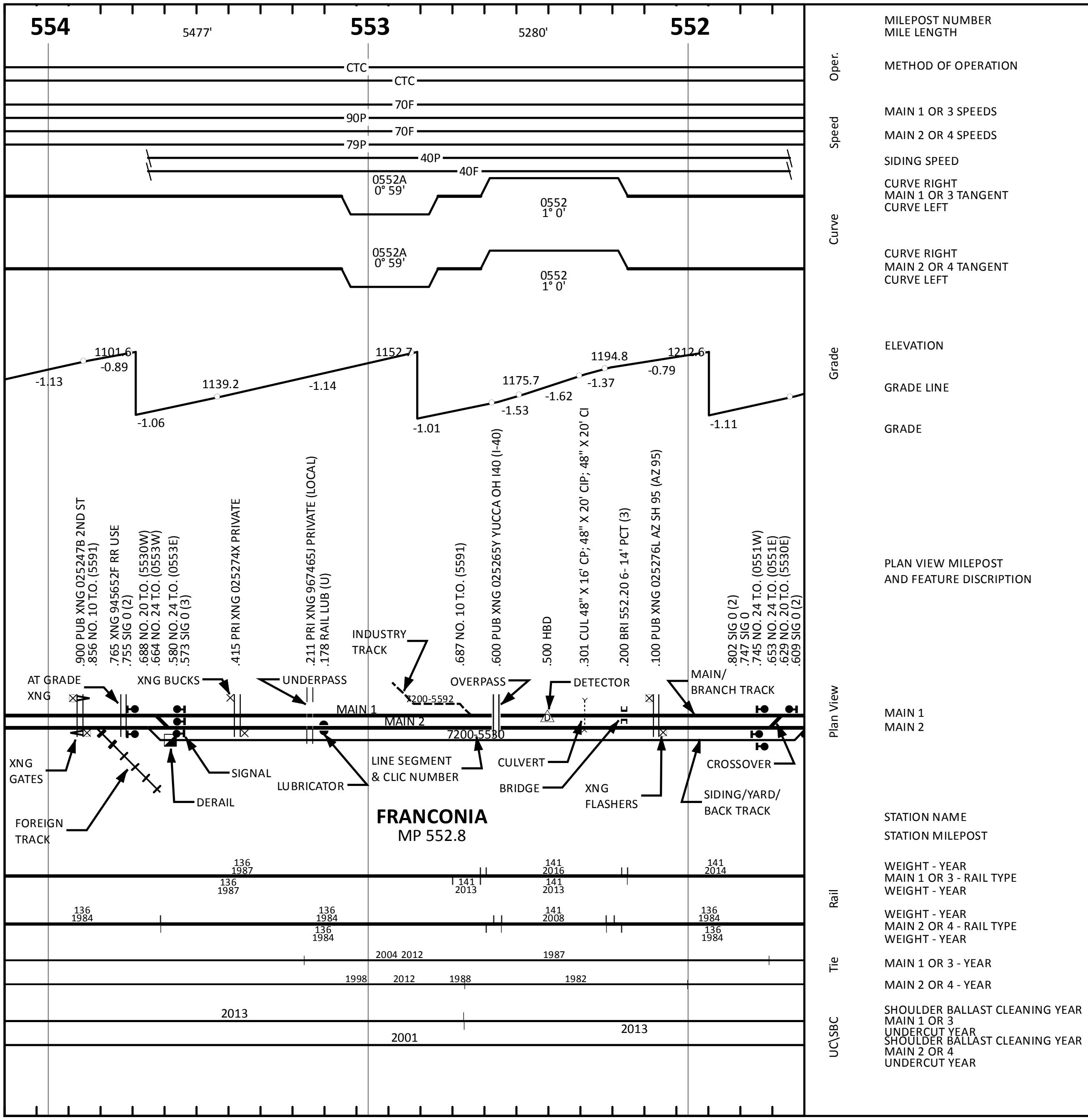
See each page for latest revised date.

Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Butte Subdivision





TRACK CHART FEATURE LEGEND

NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280')   VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

FILE: Y:\drawings\trkchrts\ASTC\MXD_Files\TC_Legend.mxd

Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

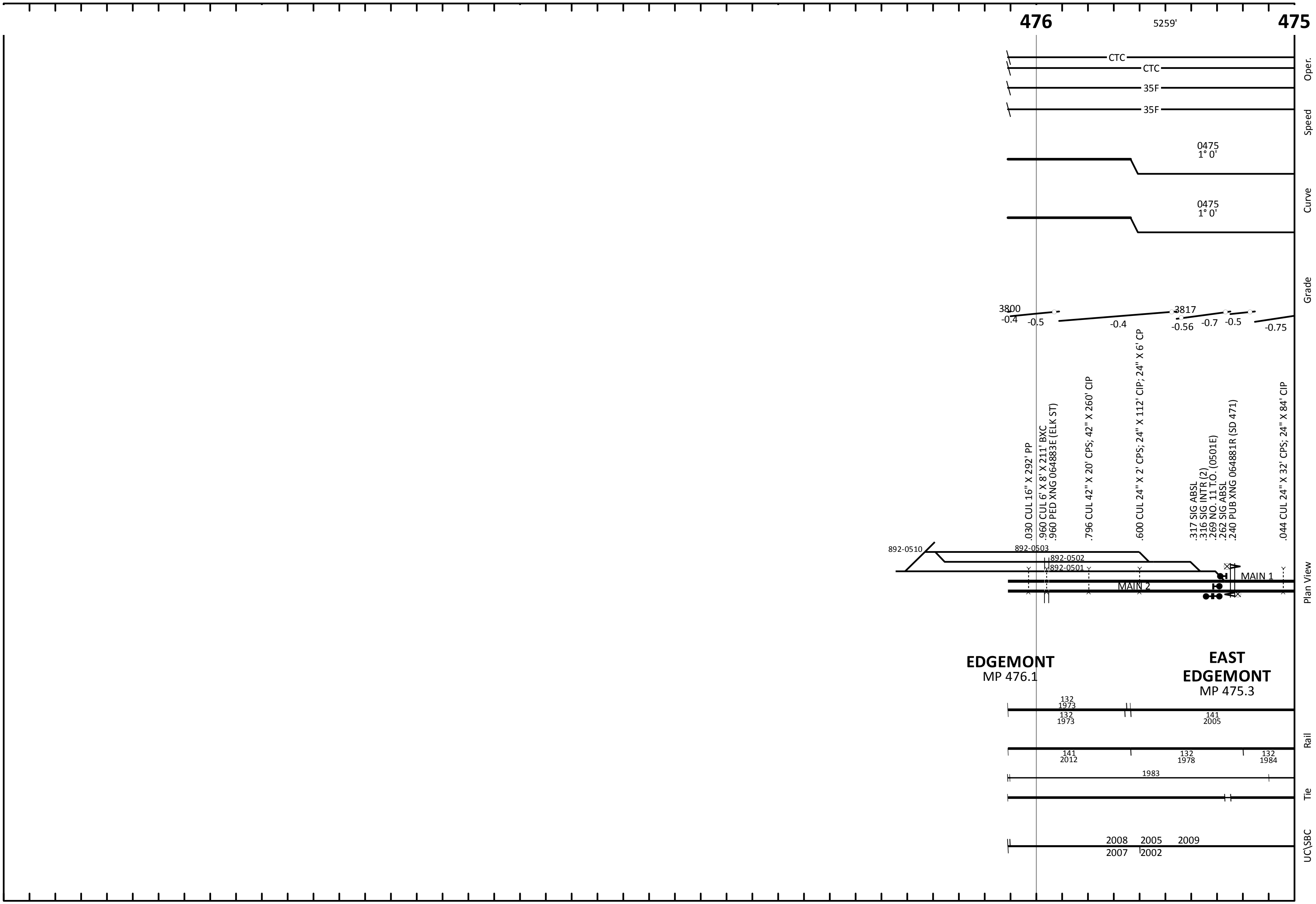
AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

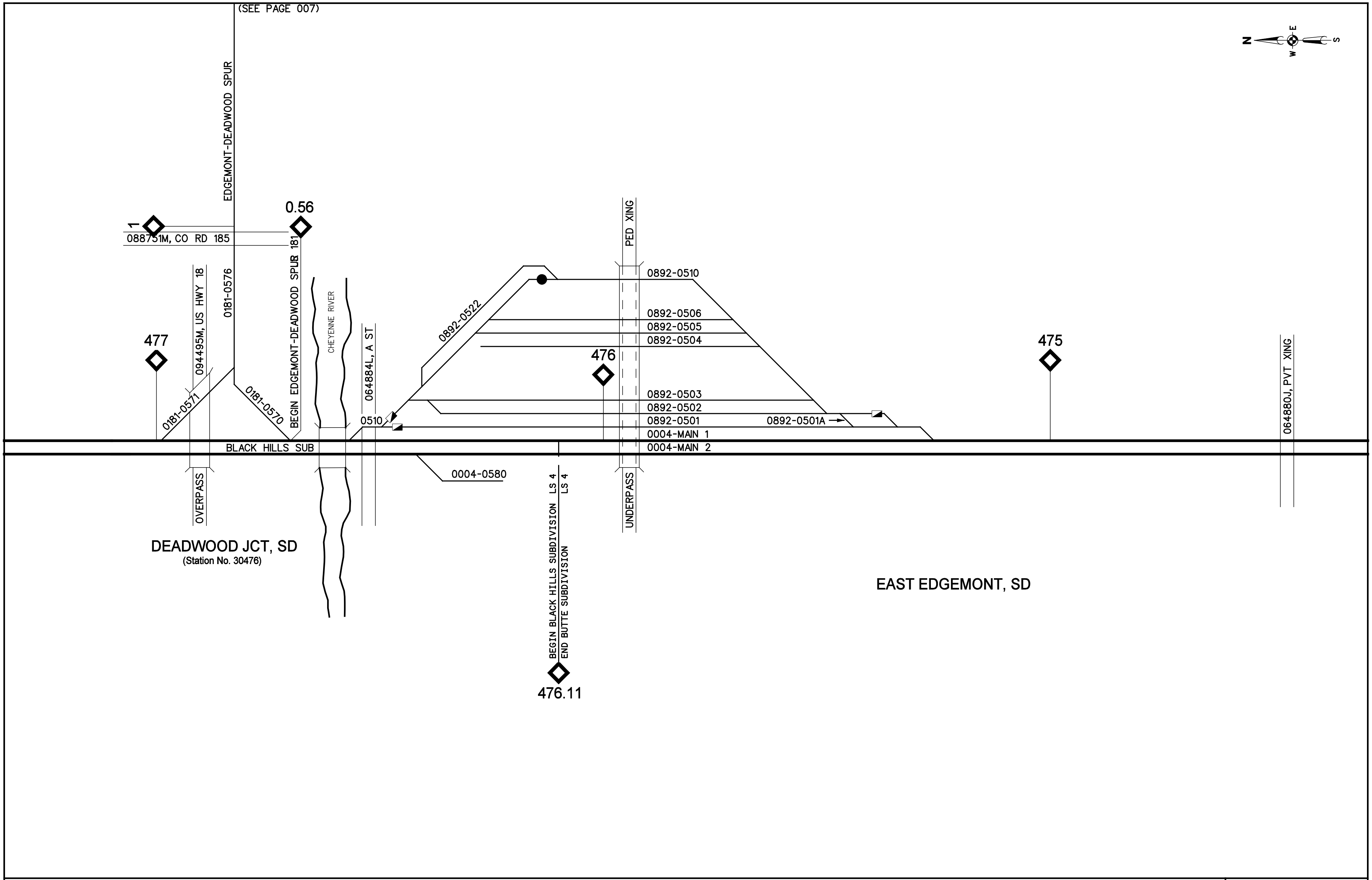
BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL


476
5259'
475
Oper.
CTC
CTC
Speed
35F
35F
Curve
0475
1° 0'
0475
1° 0'
Grade
3800
-0.4
-0.5
-0.4
3817
-0.56
-0.7
-0.5
-0.75
.030 CUL 16" X 292' PP
.960 CUL 6' X 8' X 211' BXC
.960 PED XNG 064883E (ELK ST)
.796 CUL 42" X 20' CPS; 42" X 260' CIP
.600 CUL 24" X 2' CPS; 24" X 112' CIP; 24" X 6' CP
.317 SIG ABSL
.316 SIG INTR (2)
.269 NO. 11 T.O. (0501E)
.262 SIG ABSL
.240 PUB XNG 064881R (SD 471)
.044 CUL 24" X 32' CPS; 24" X 84' CIP
Plan View
892-0510
892-0503
892-0502
892-0501
MAIN 1
MAIN 2
EDGEMONT
MP 476.1
EAST
EDGEMONT
MP 475.3
Rail
132
1973
132
1973
141
2005
141
2012
132
1978
132
1984
Tie
1983
UC\SBC
2008
2007
2005
2002
2009

EDGEMONT, SD
Butte Subdivision

← West Gillette, WY

East Alliance, NE →



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

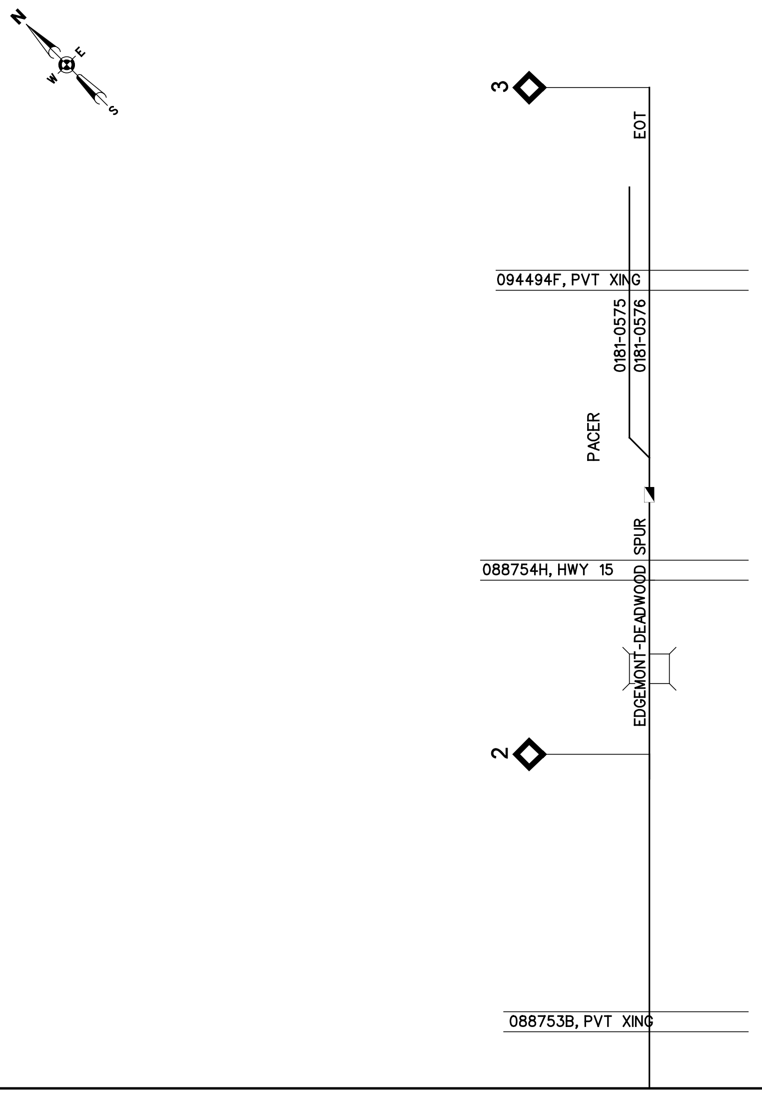
REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
SPECIAL CONDITIONS (ITEM *7)
FOR ADDITIONAL QUESTIONS ON PHYSICAL CHARACTERISTICS, CONTACT A LOCAL DIVISION MANAGER
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

———	BNSF OWNED & MAINT	—┼—┼—	JOINT FACILITIES
—◆—◆—	INDUSTRY OWNED & BNSF MAINT	▬	TRACKAGE RIGHTS
— — — —	IND OWNED & MAINT	┼┼┼┼	FOREIGN TRACK
●—●—●	INDUSTRY MAINT & BNSF OWNED (LEASE)		
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT		
◪	DERAIL		

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: EDGEMO
FSAC: 30475
REVISED: 5/3/2016
TEAM: EDGE05003.DGN
TRK CHT: BUT006.DGN
TEAM PG 003

EDGEMONT, SD
Butte Subdivision



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INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
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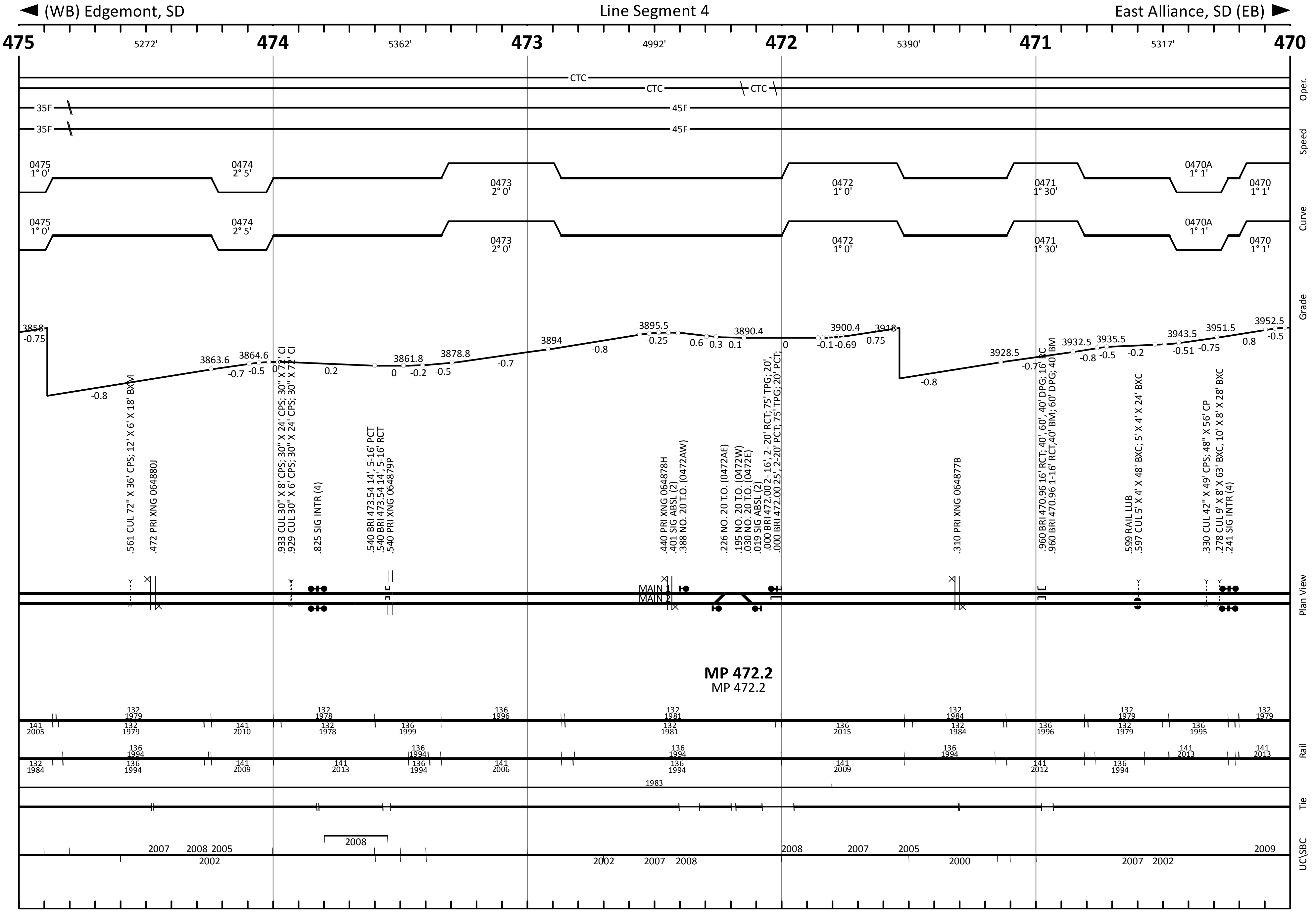
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: EDGEMO
FSAC: 30475
REVISED: 11/5/2014
TEAM: EDGE05005.DGN
TRK CHT: BUT007.DGN



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

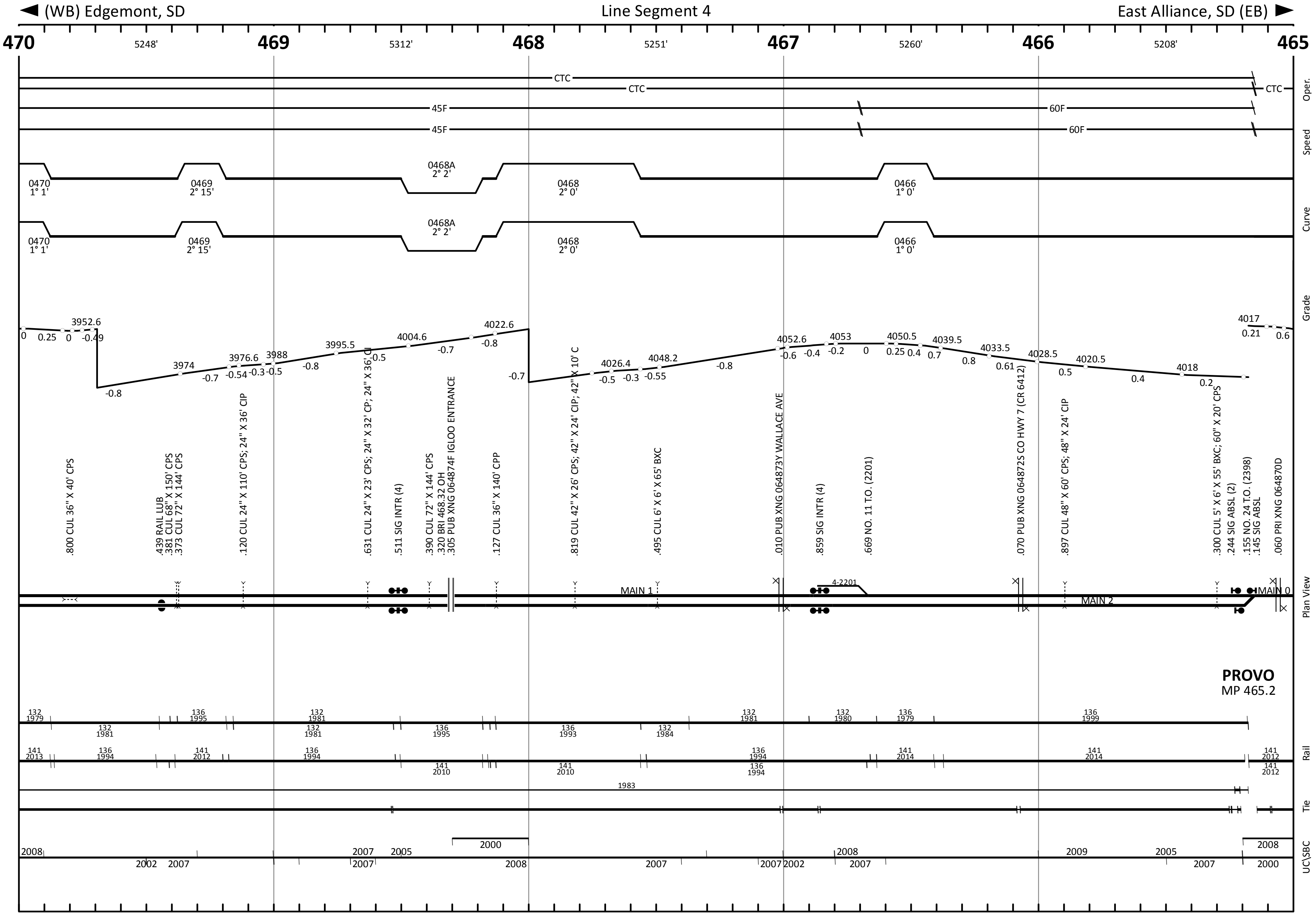
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

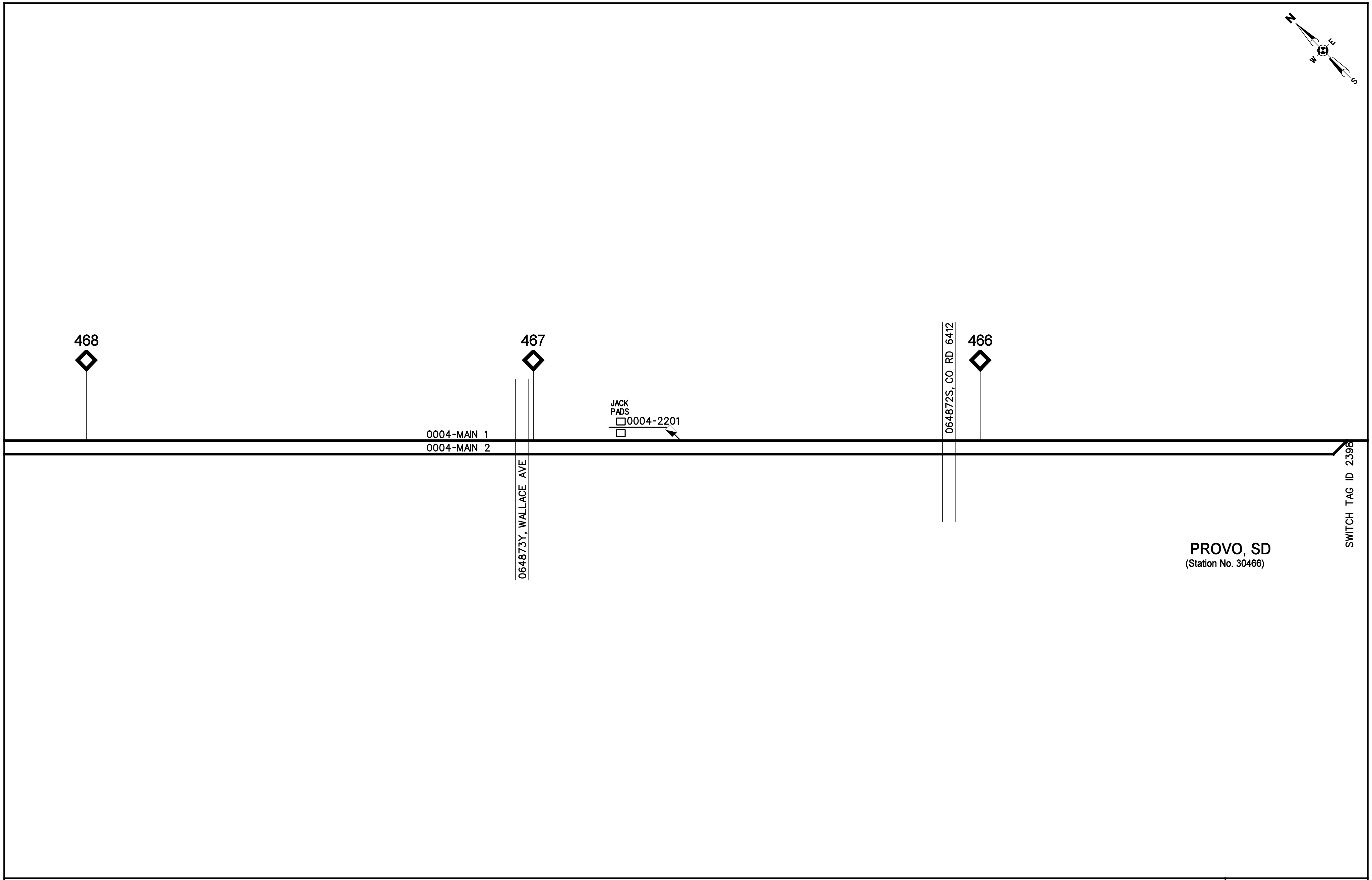
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018 Page 9 of 41

AREA WYE, SD
Butte Subdivision

← Edgemont, SD

East Alliance, NE →



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INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
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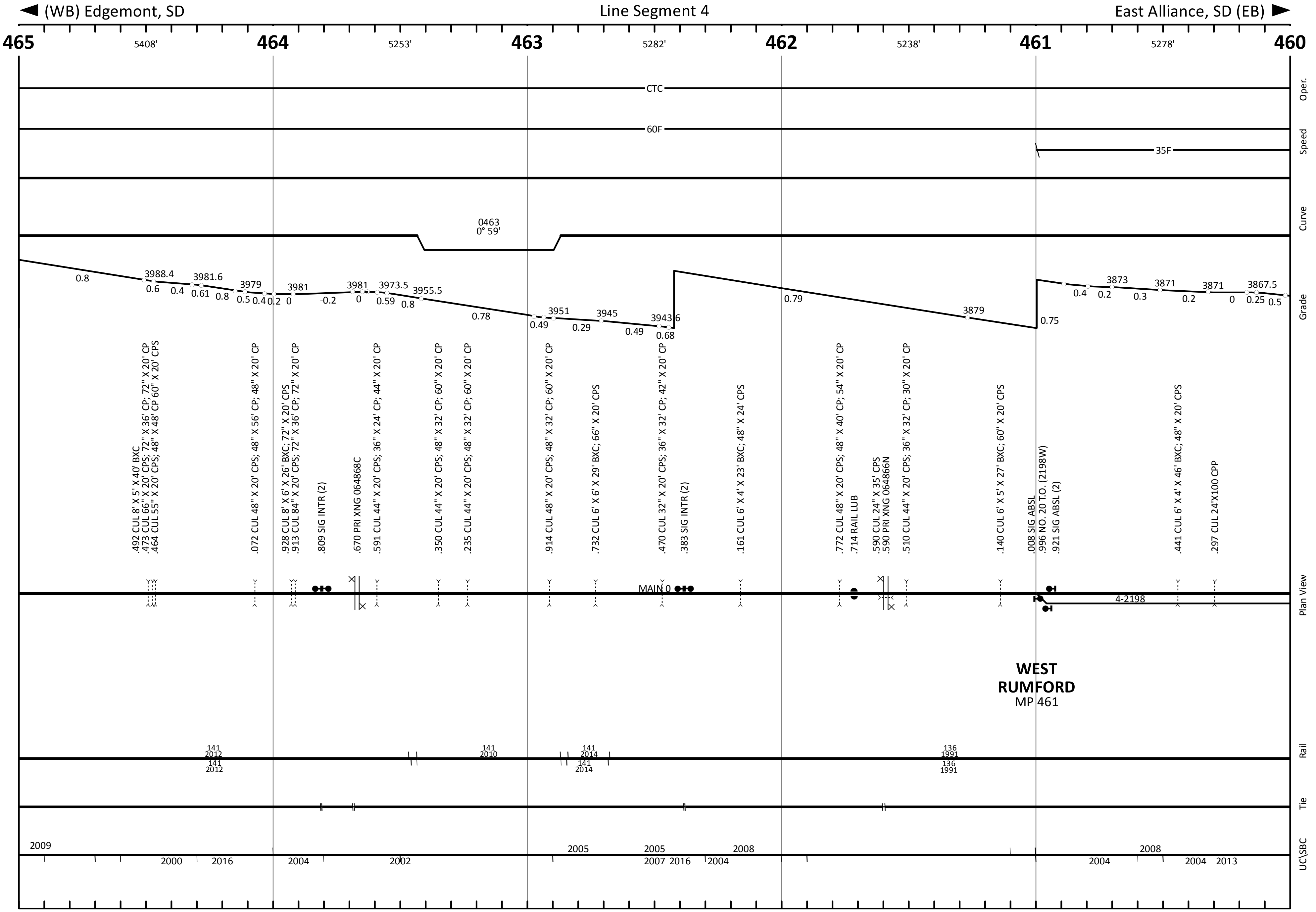
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: AREWYE
FSAC: 30467
REVISED: 11/5/2014
TEAM: AREA22007.DGN
TRK CHT: BUT010.DGN
TEAM PG 007



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

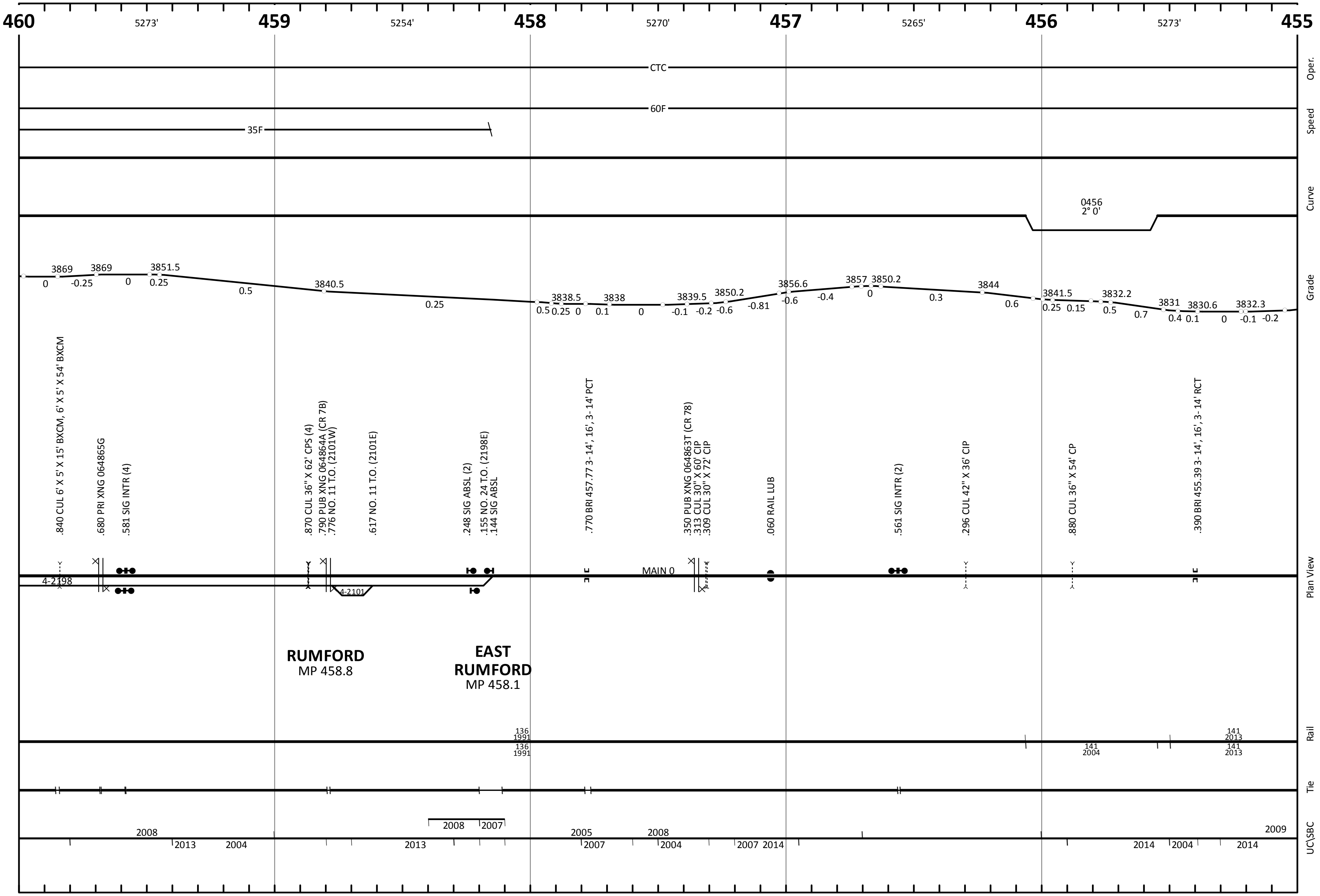
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

◄ (WB) Edgemont, SD   Line Segment 4   East Alliance, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

Powder River Operating Division
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

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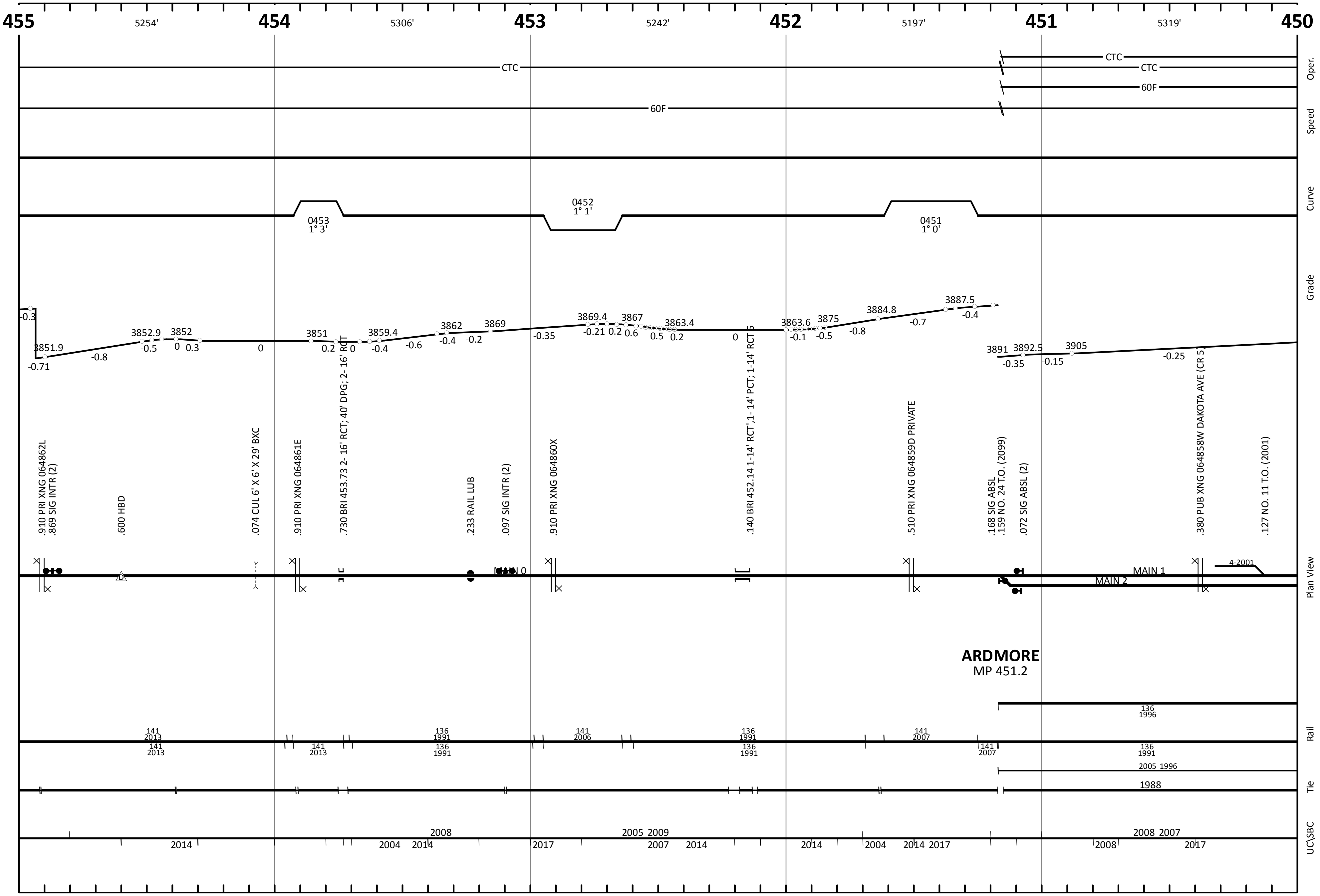

BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

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Powder River North Engineering Division

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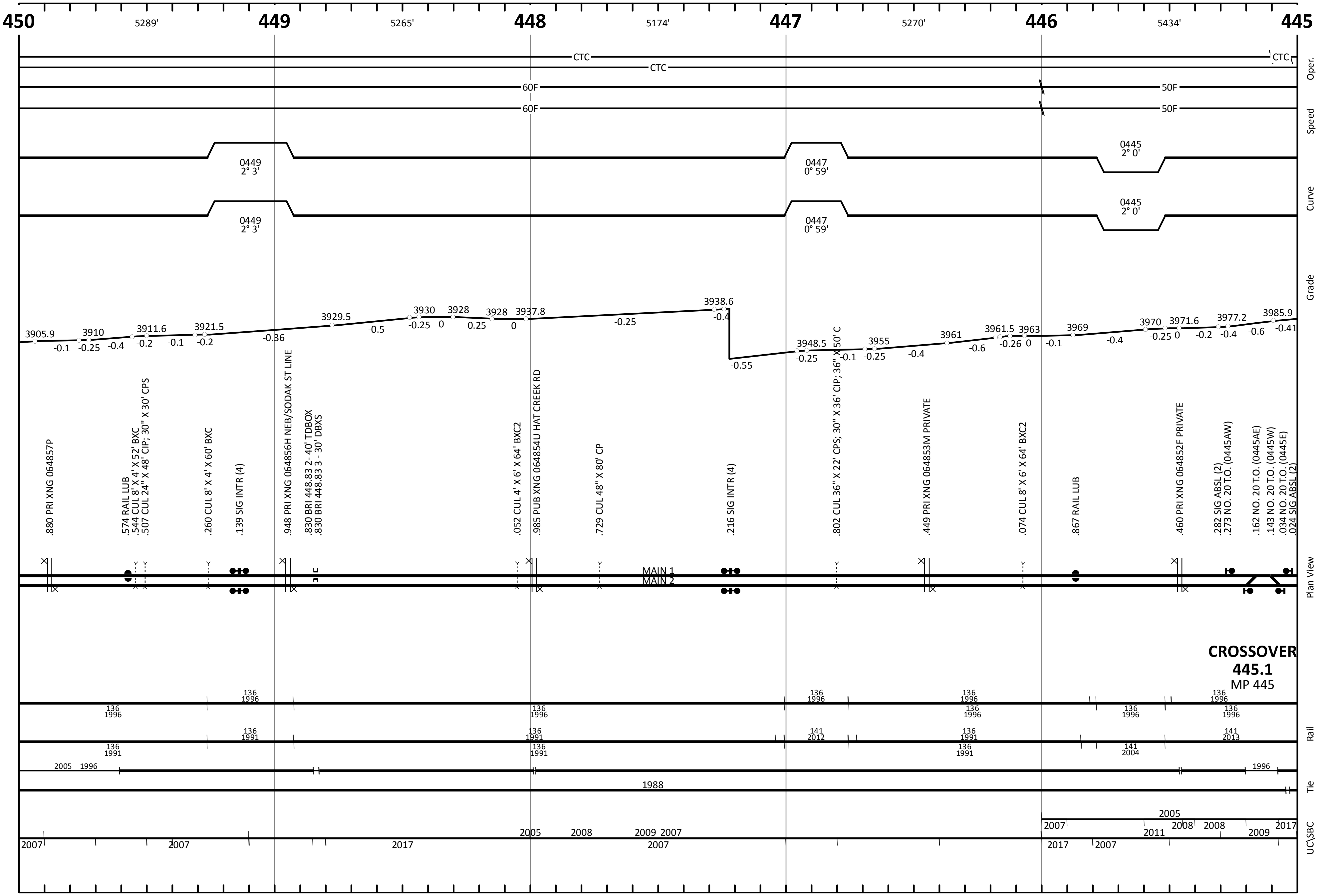
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

◀ (WB) Edgemont, SD Line Segment 4 East Alliance, SD (EB) ▶



BNSF RAILWAY

System Maintenance and Planning

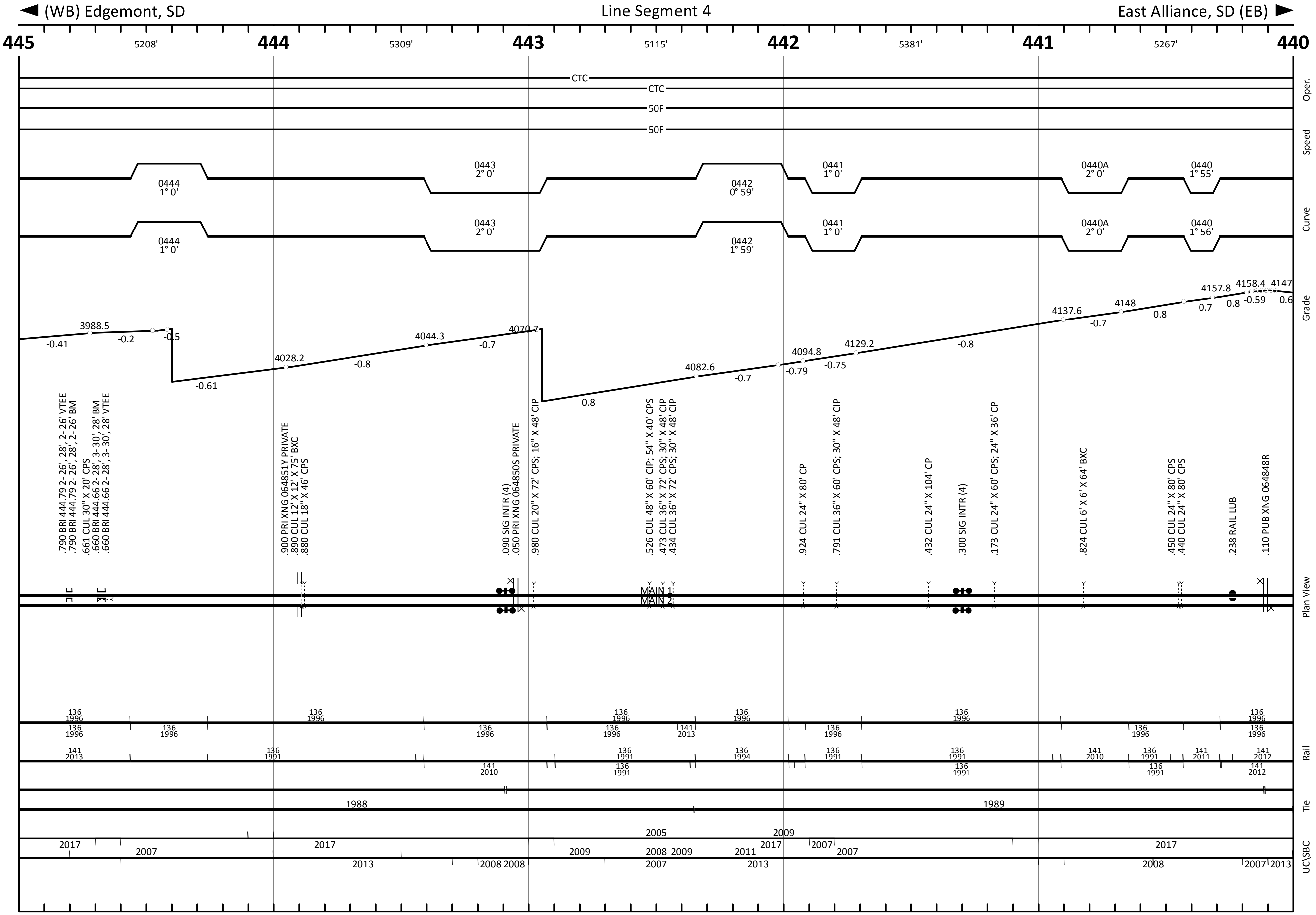
Butte Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

Powder River Operating Division

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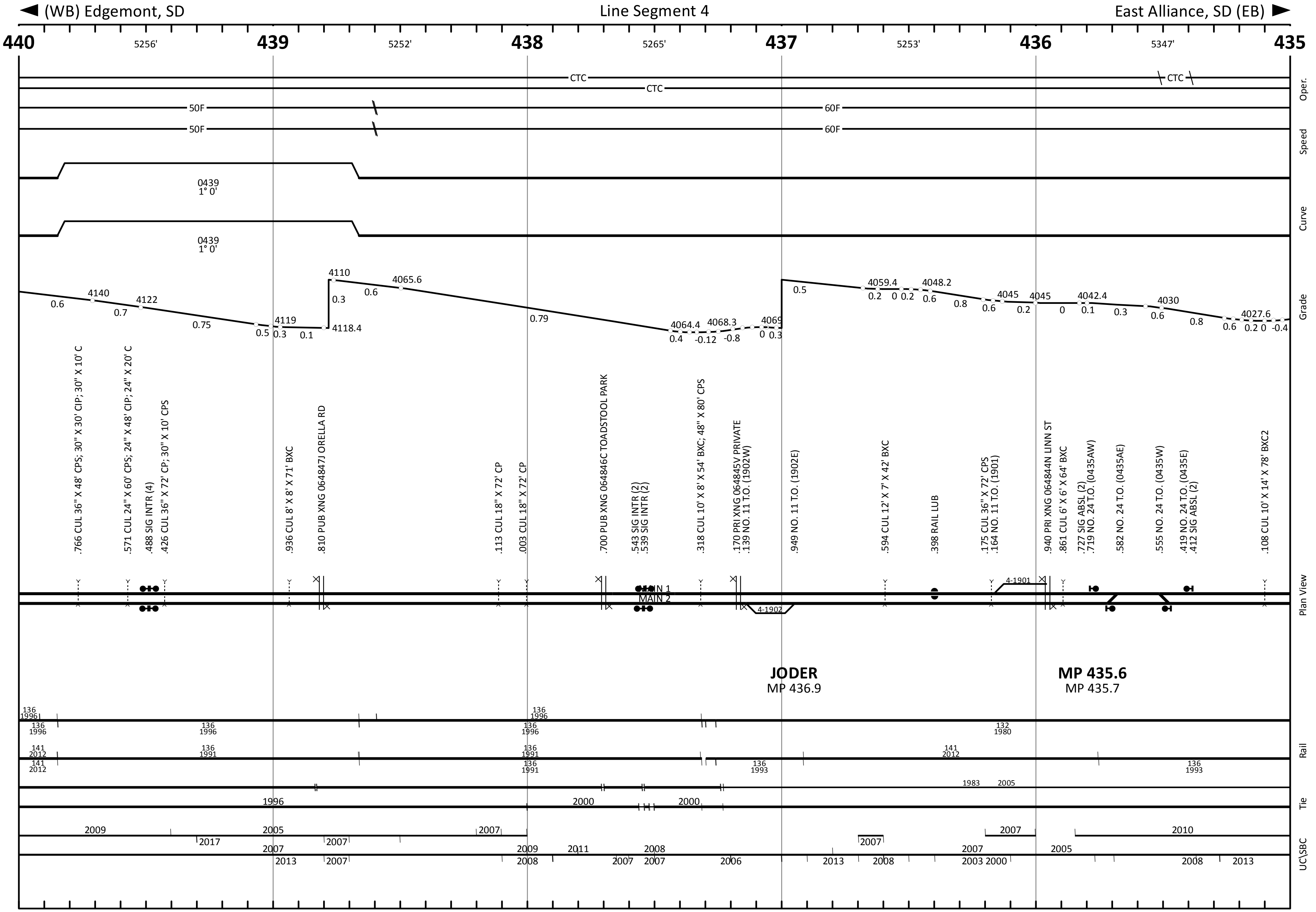
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

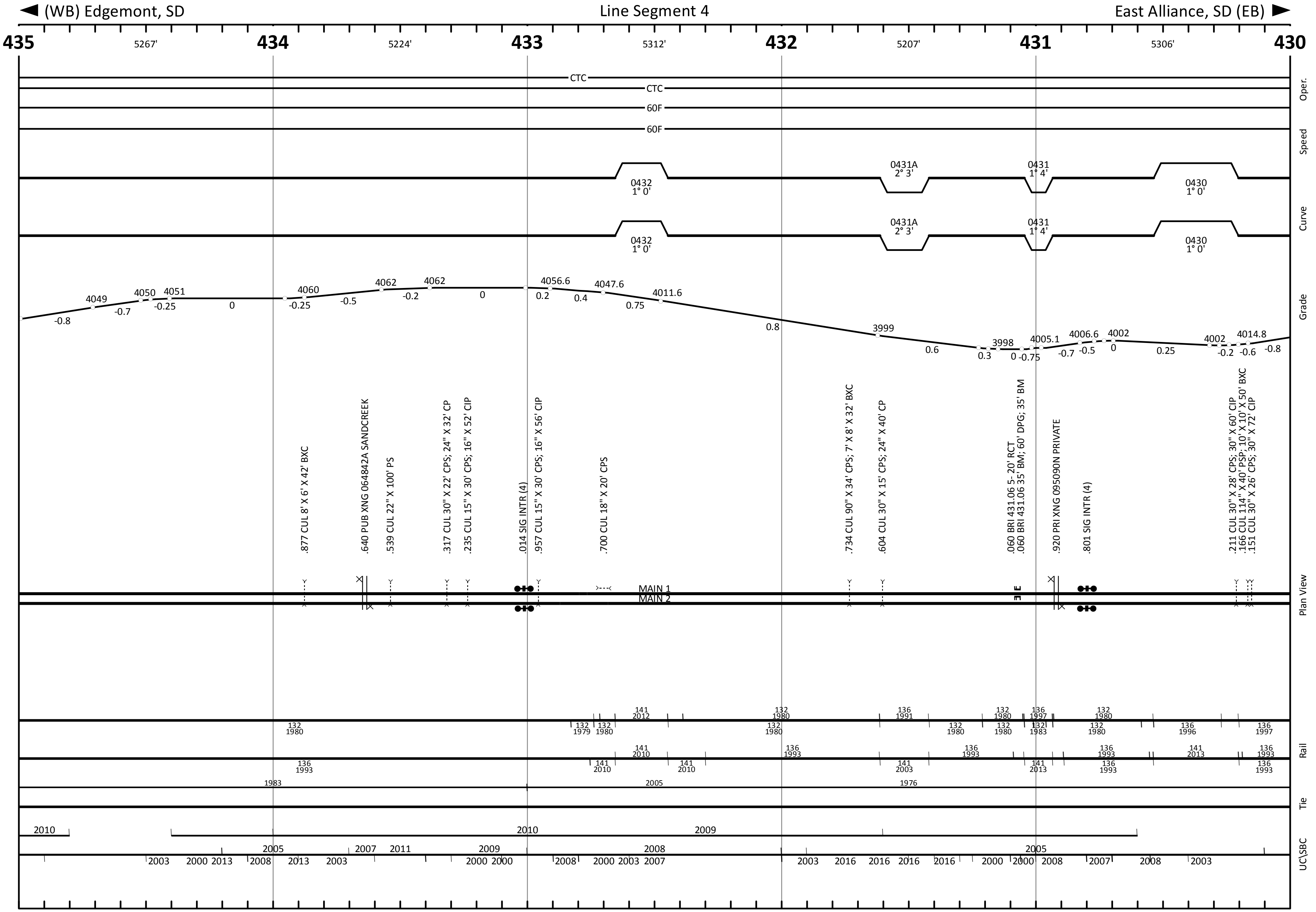
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018 Page 16 of 41



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

Powder River Operating Division

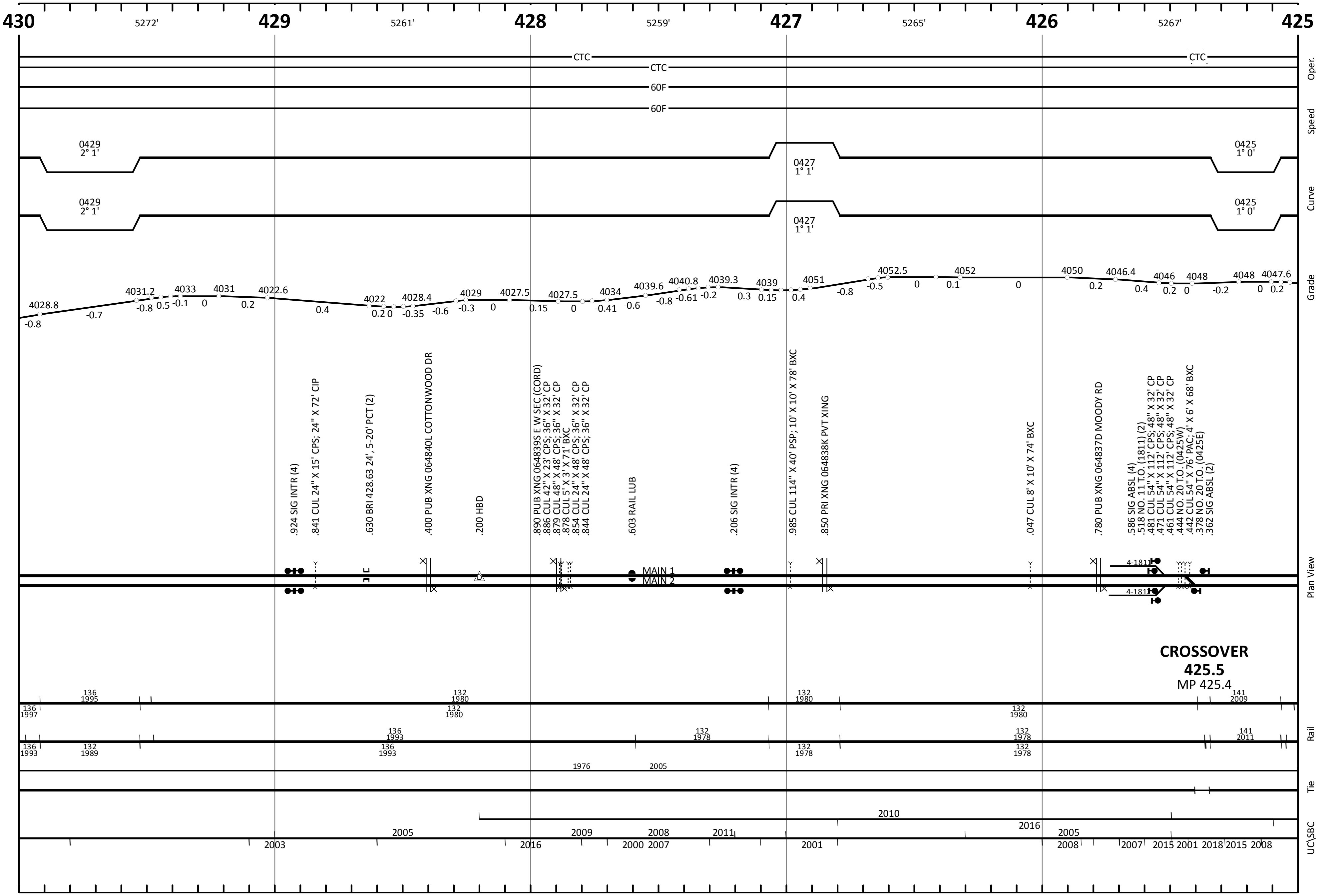
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018 Page 17 of 41

◄ (WB) Edgemont, SD   Line Segment 4   East Alliance, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

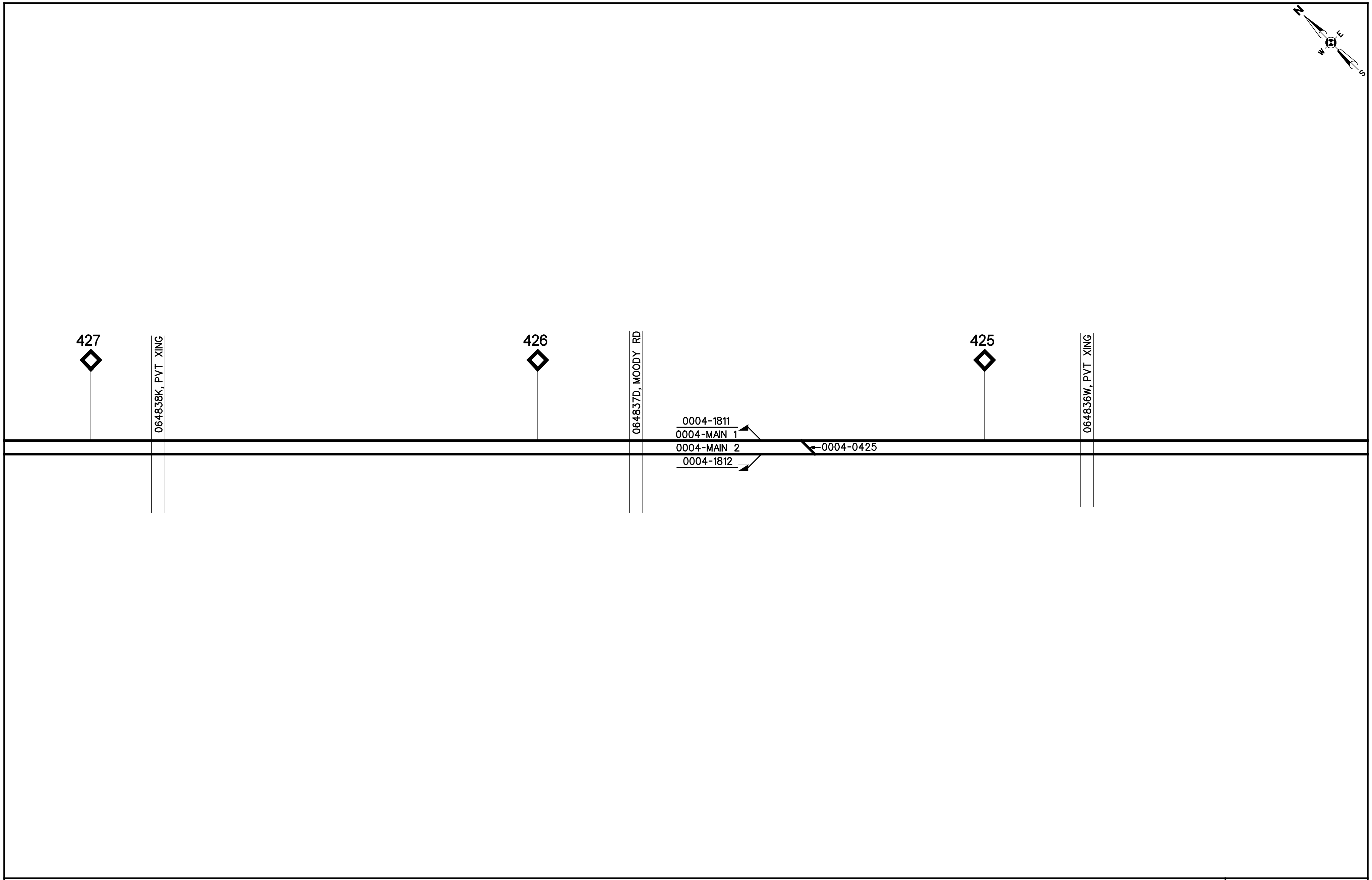
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

CRAWFORD, NE
Butte Subdivision

← Edgemont, SD

East Alliance, NE →



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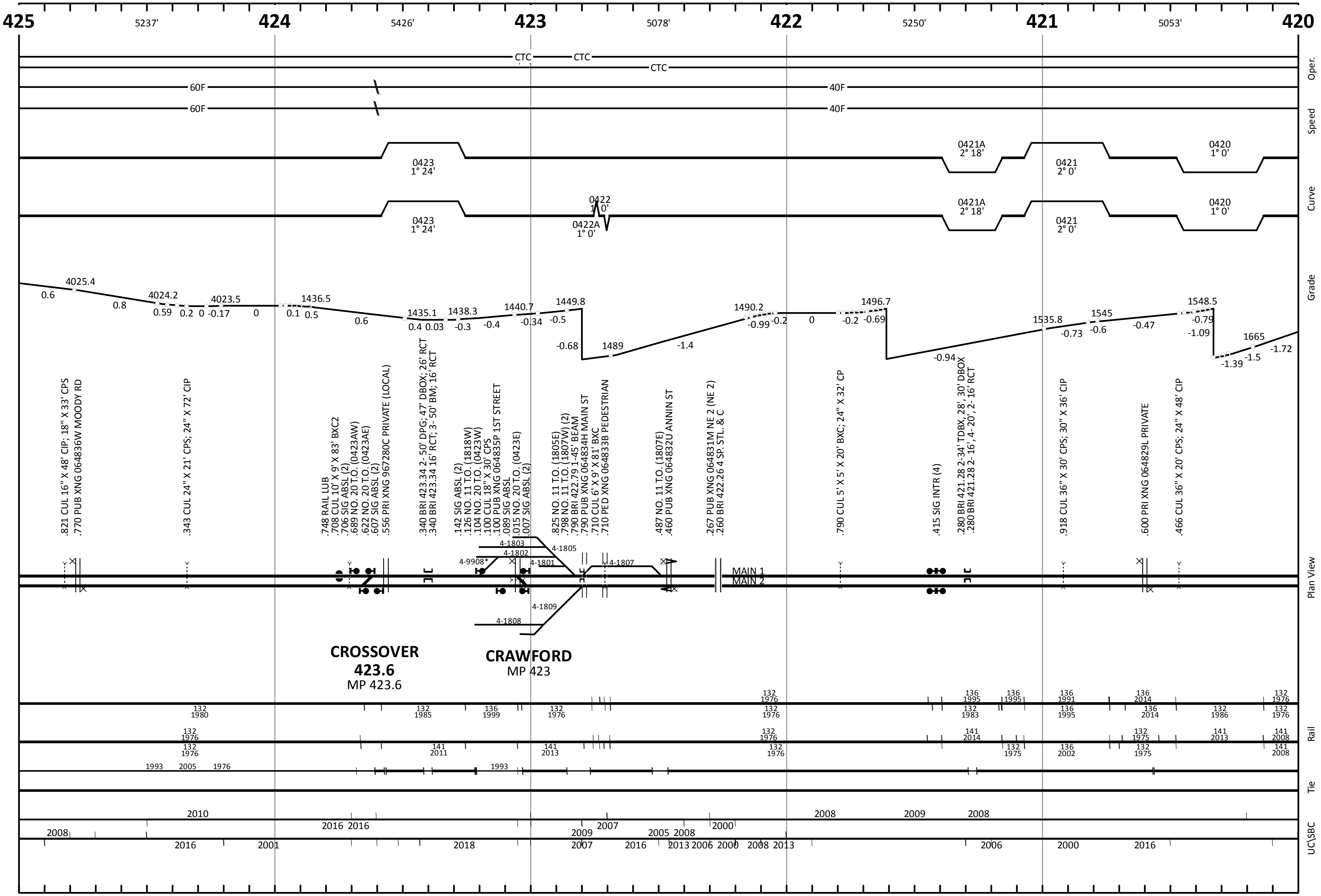
BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: CRAWNE
FSAC: 30422
REVISED: 11/5/2014
TEAM: CRAW18015.DGN
TRK CHT: BUT019.DGN
TEAM PG 015

◄ (WB) Edgemont, SD — Line Segment 4 — East Alliance, SD (EB) ►



BNSF RAILWAY
System Maintenance and Planning

Butte Subdivision

Powder River Operating Division
Powder River North Engineering Division

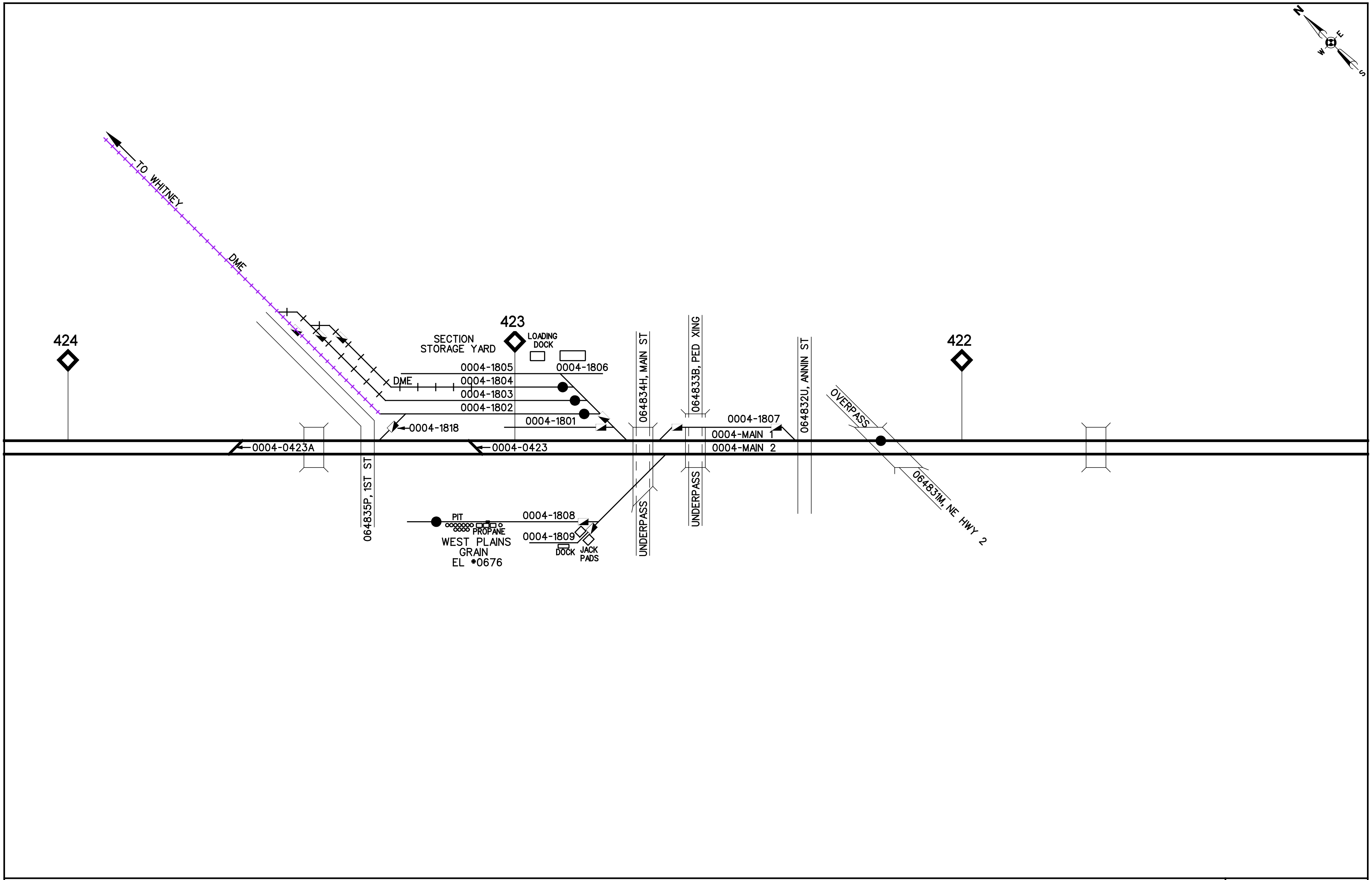
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 11, 2018

CRAWFORD, NE
Butte Subdivision

← Edgemont, SD

East Alliance, NE →



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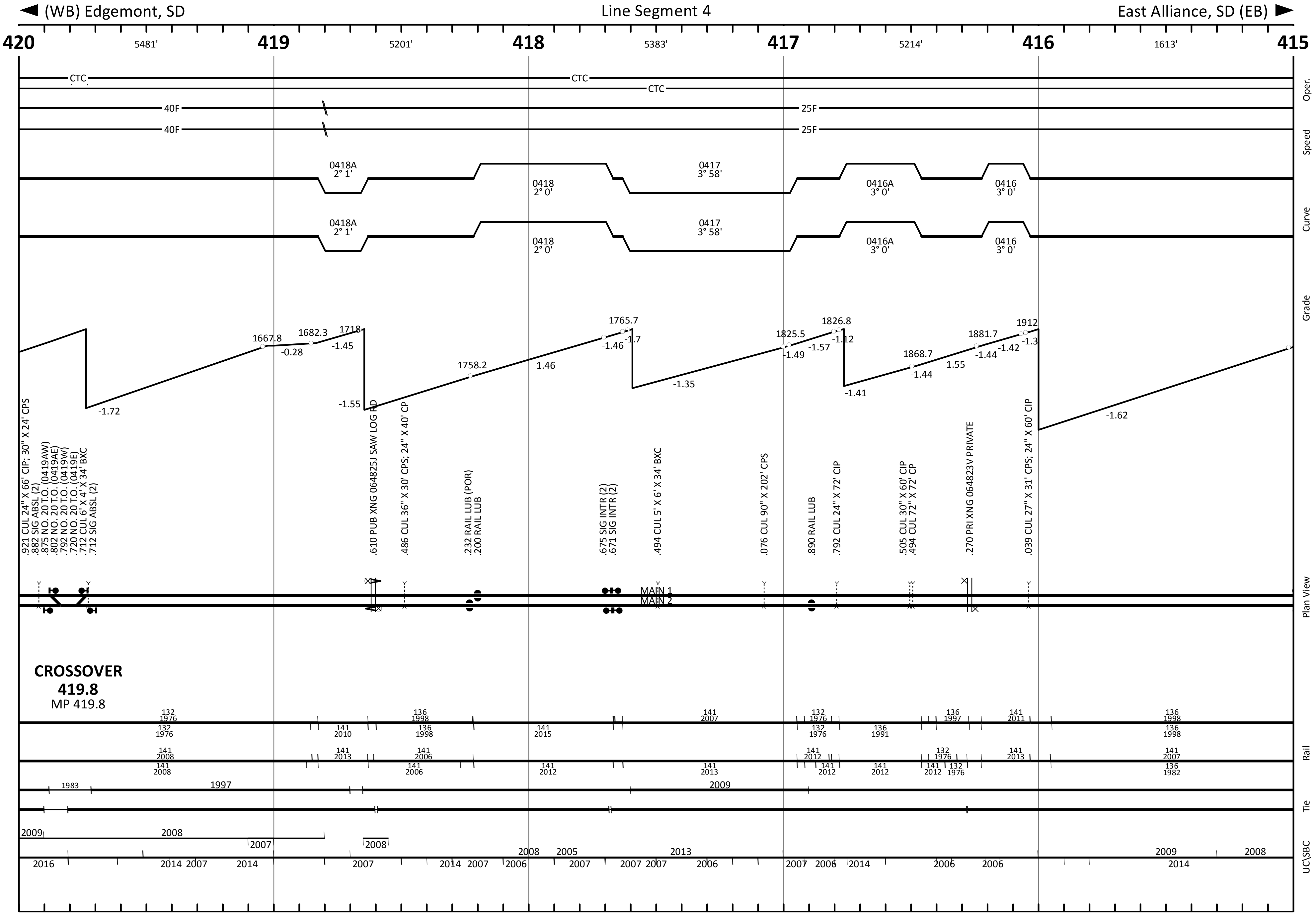
—◆—◆—	INDUSTRY OWNED & BNSF MAINT
— — —	IND OWNED & MAINT
—●—●—●—	INDUSTRY MAINT & BNSF OWNED (LEASE)
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪	DERAIL
—┼—┼—	JOINT FACILITIES
———	TRACKAGE RIGHTS
—┼—┼—┼—	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: CRAWNE
FSAC: 30422
REVISED: 11/5/2014
TEAM: CRAW18017.DGN
TRK CHT: BUT021.DGN



System Maintenance and Planning

Butte Subdivision

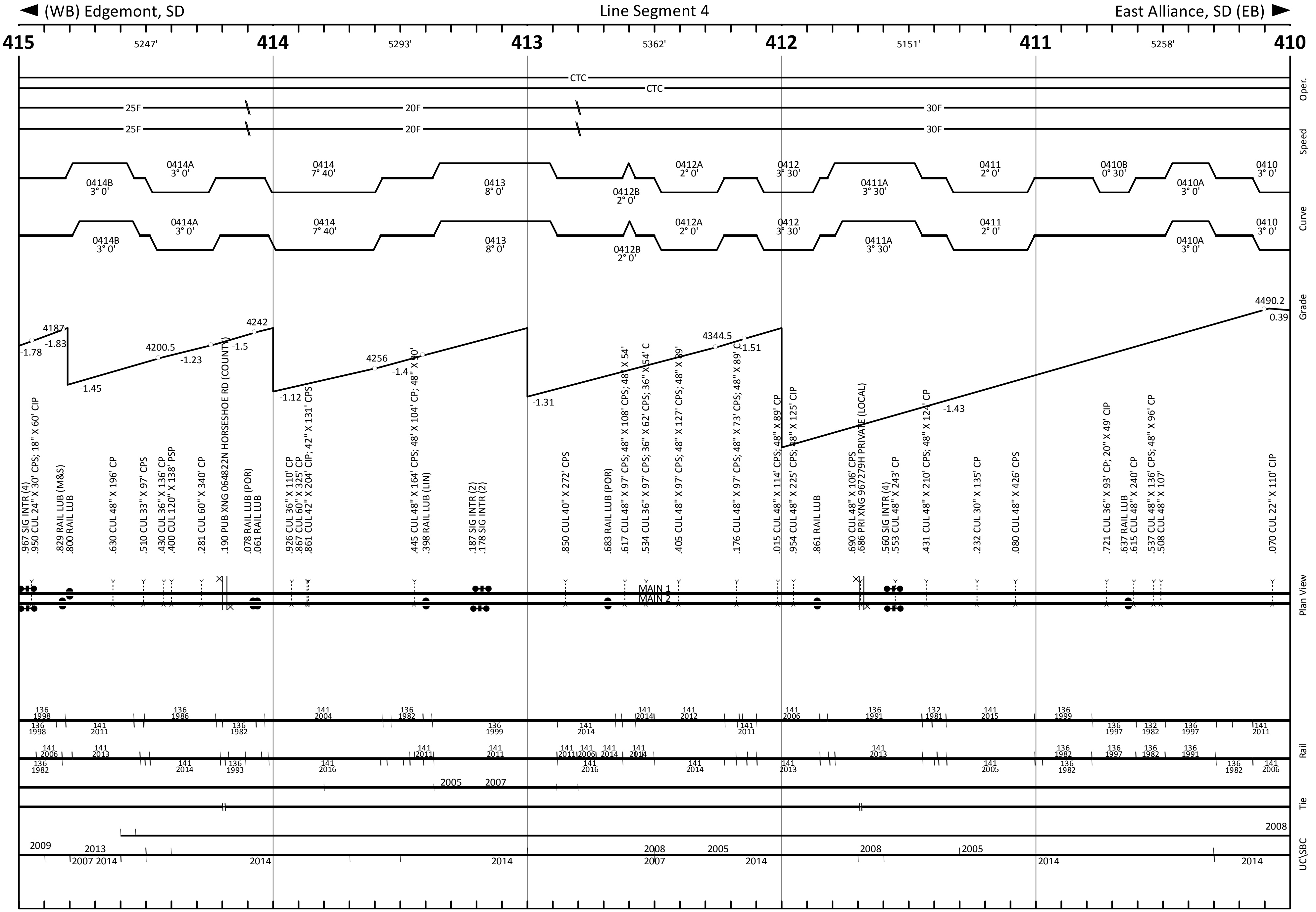
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

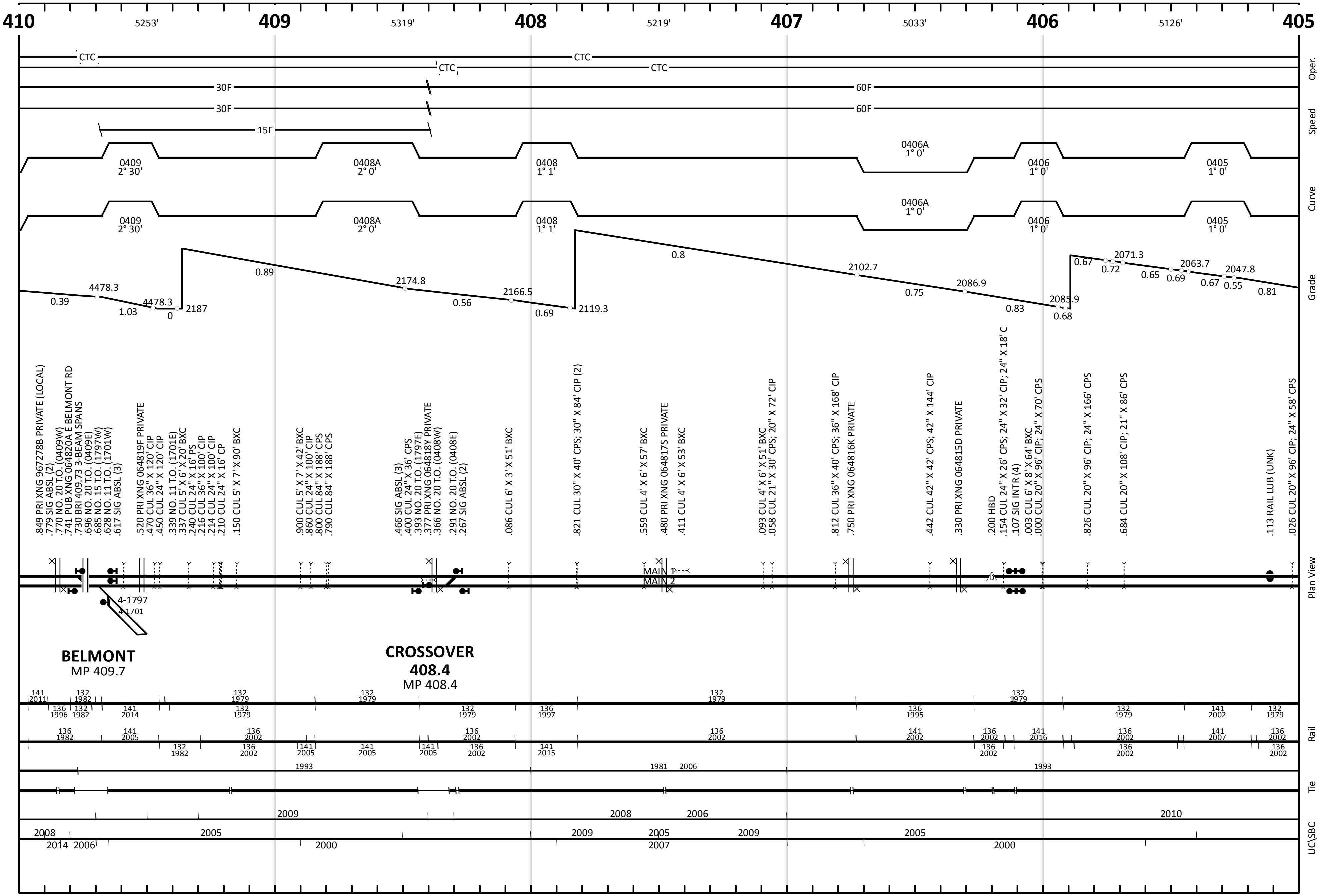
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

◄ (WB) Edgemont, SD   Line Segment 4   East Alliance, SD (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

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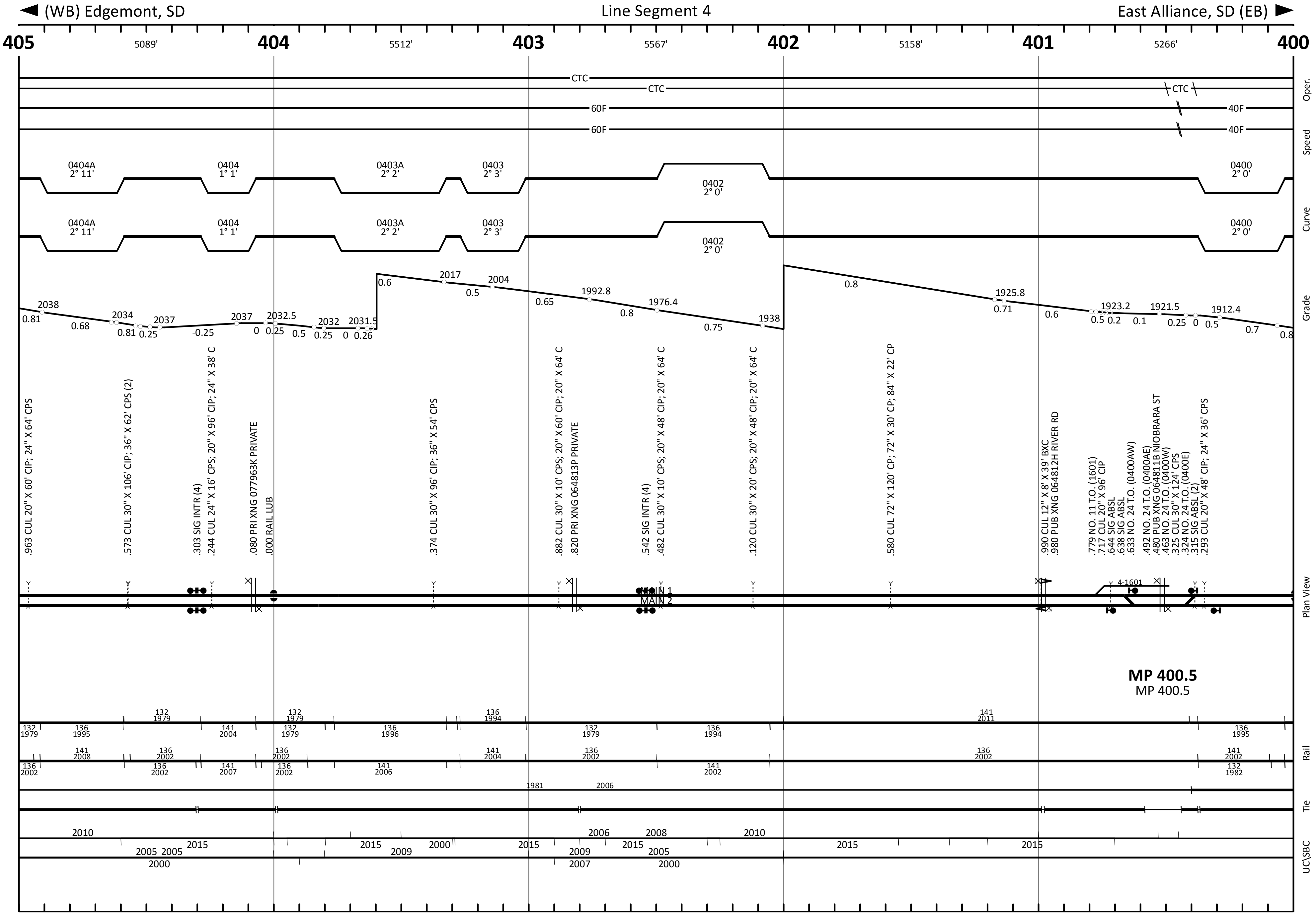
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



System Maintenance and Planning

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Powder River North Engineering Division

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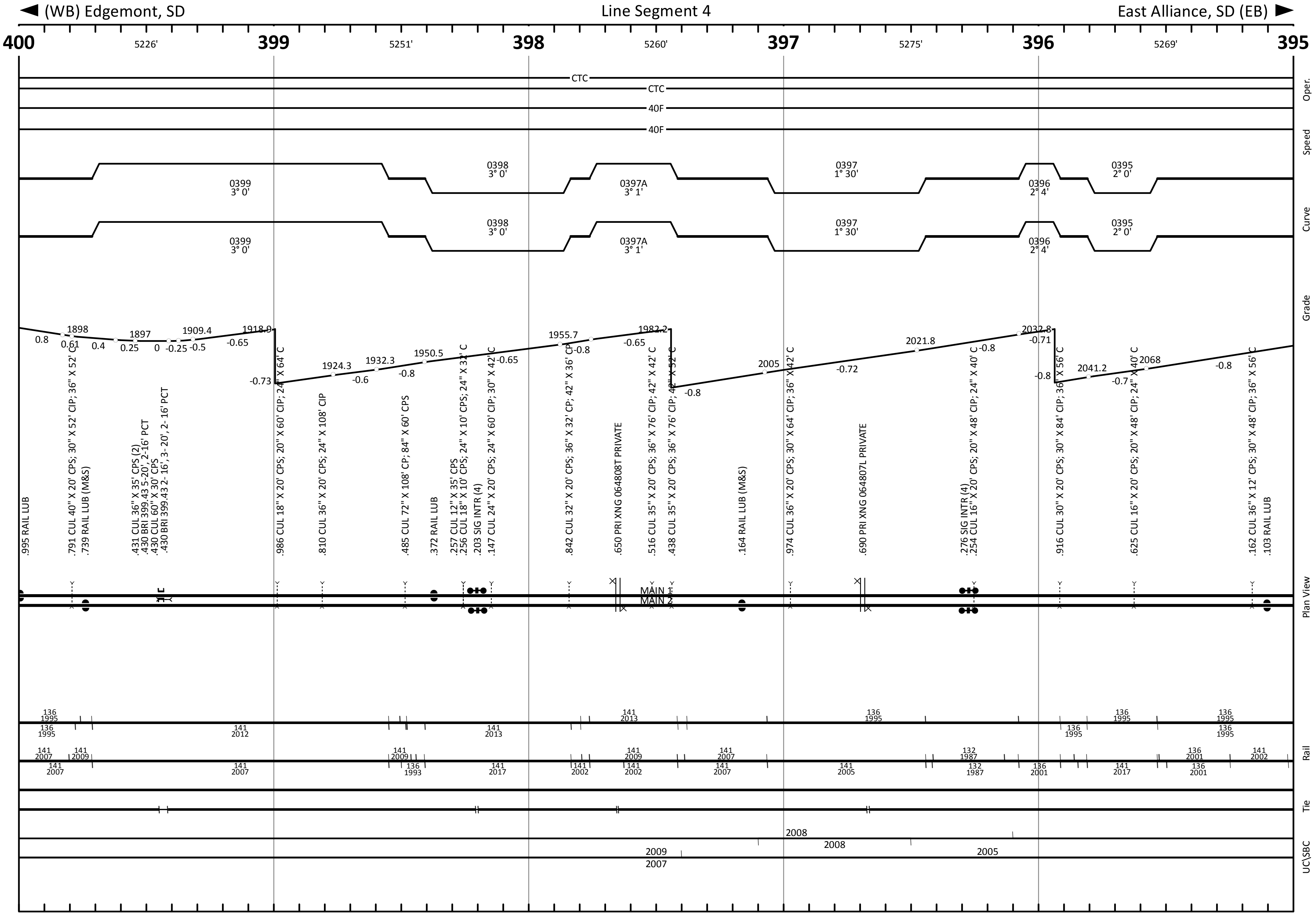
Revised to June 11, 2018



System Maintenance and Planning

Butte Subdivision

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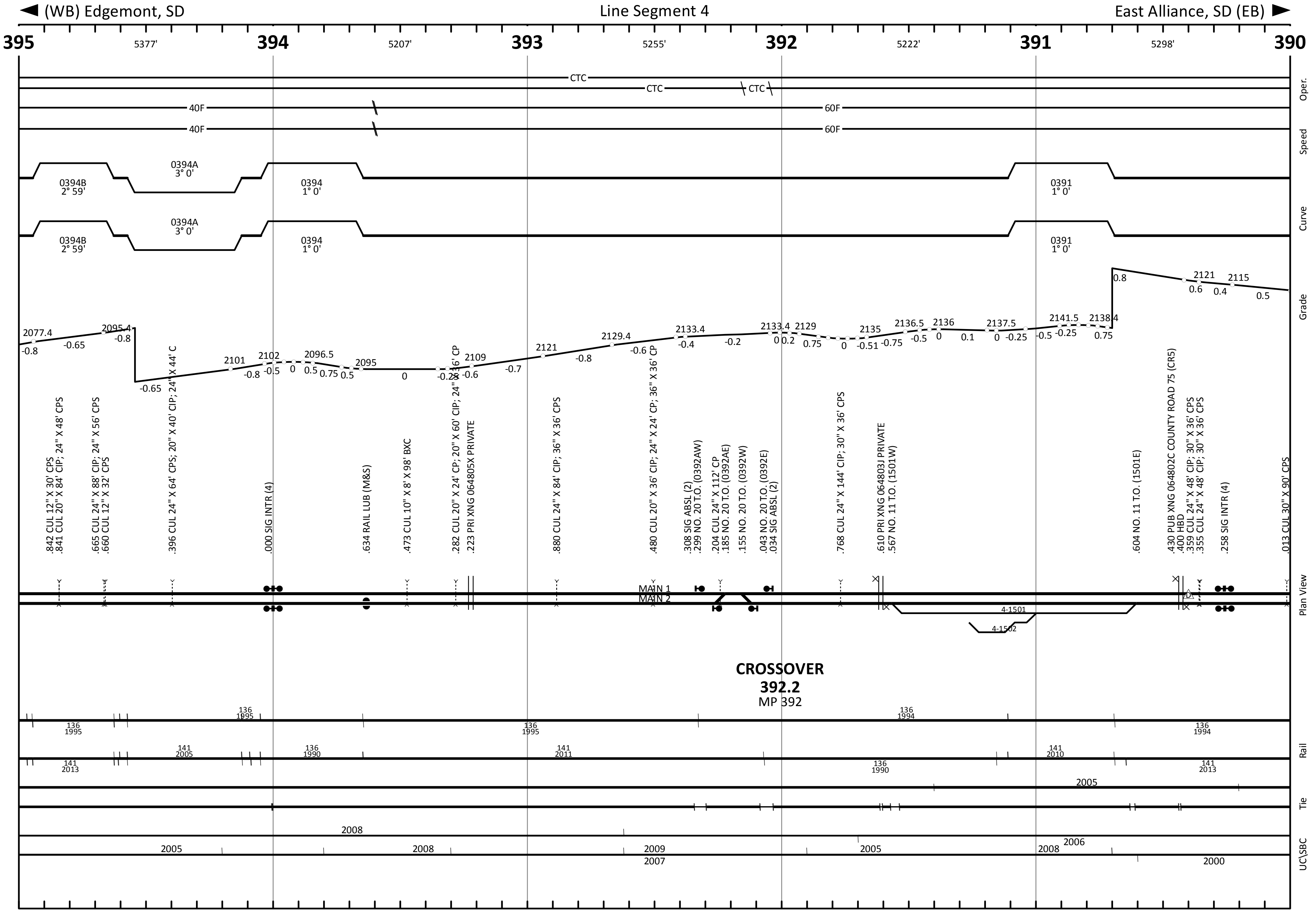

BNSF RAILWAY

System Maintenance and Planning

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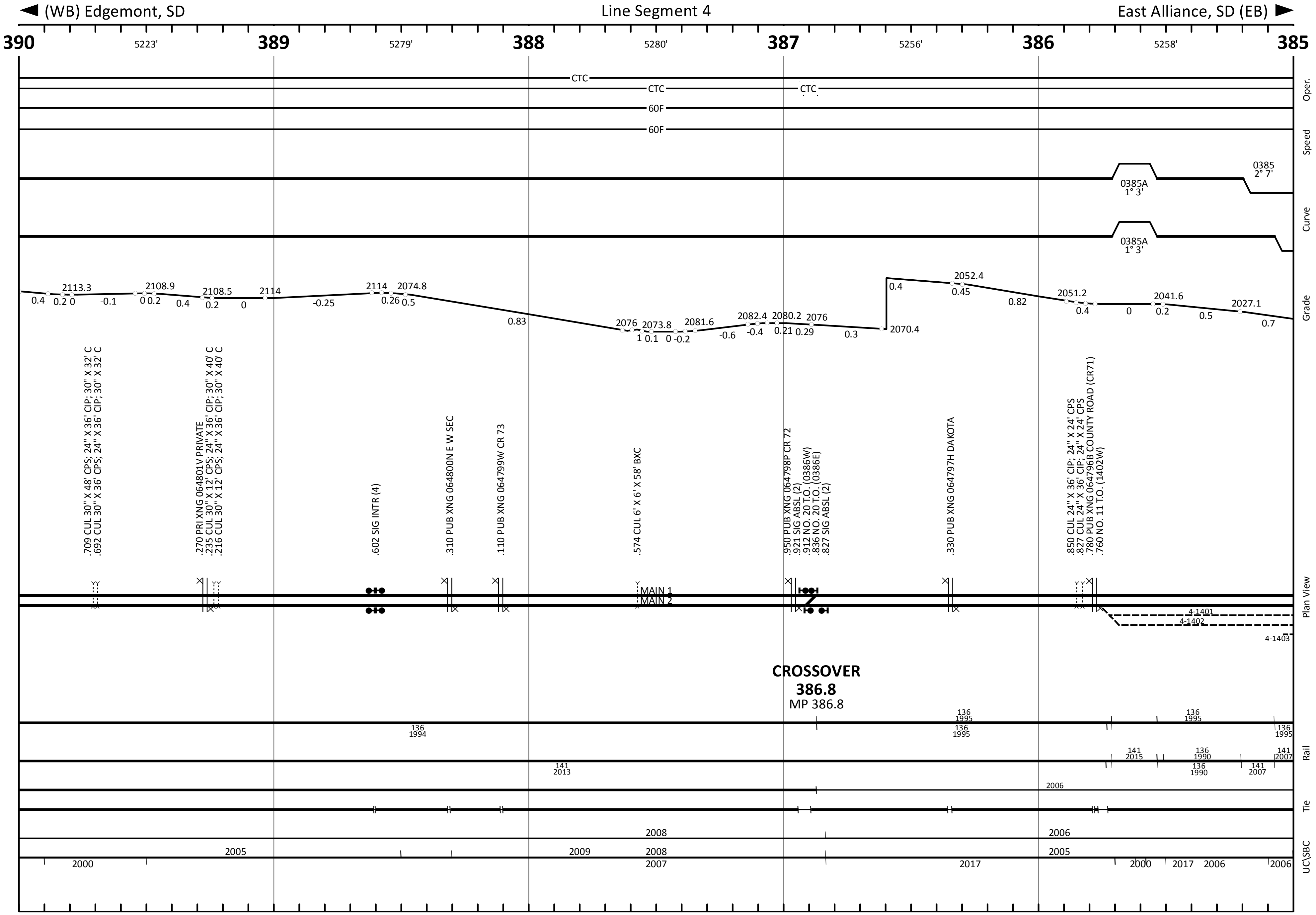

System Maintenance and Planning

Butte Subdivision

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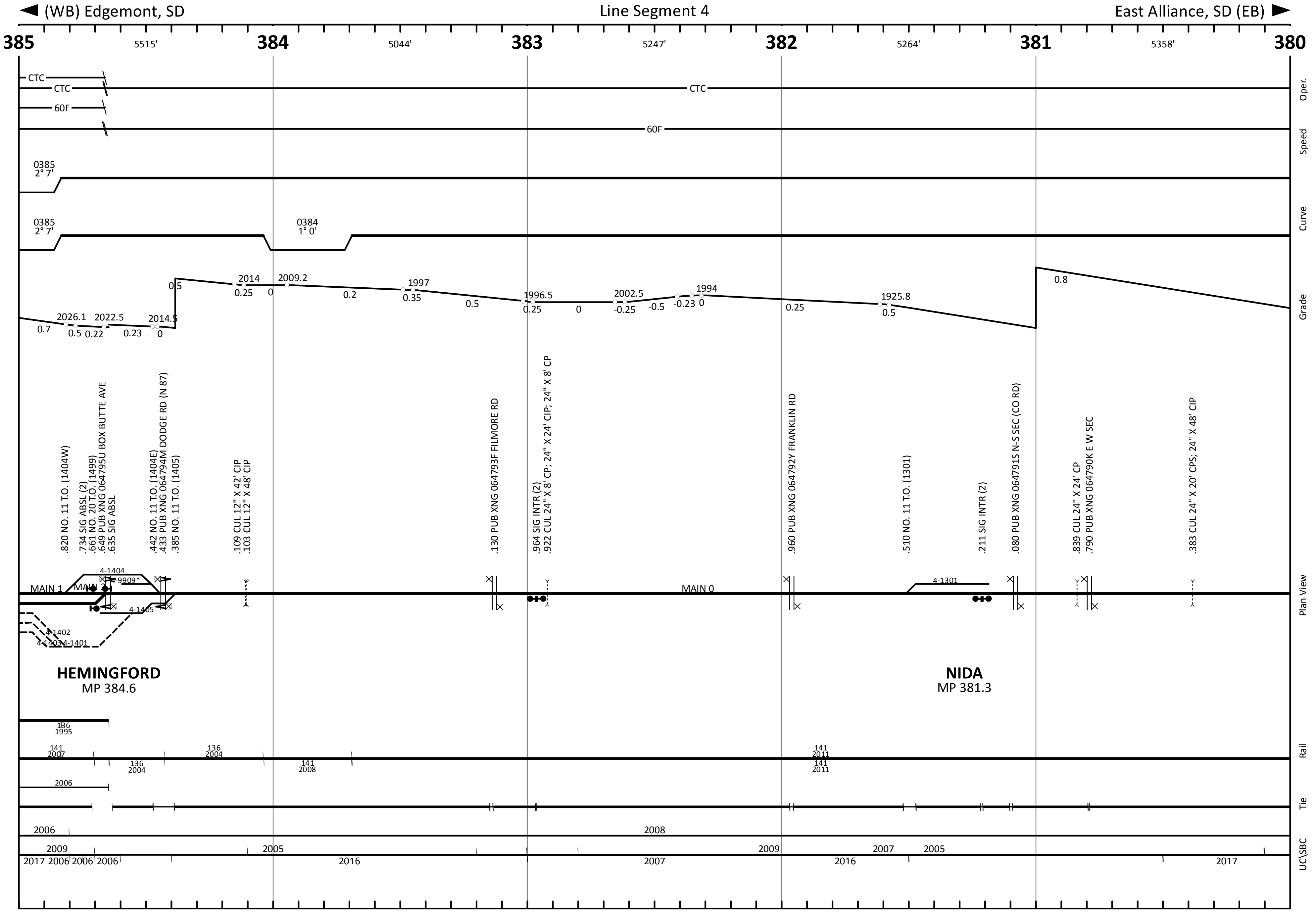
Revised to June 11, 2018



System Maintenance and Planning

Butte Subdivision

Powder River Operating Division
Powder River North Engineering Division

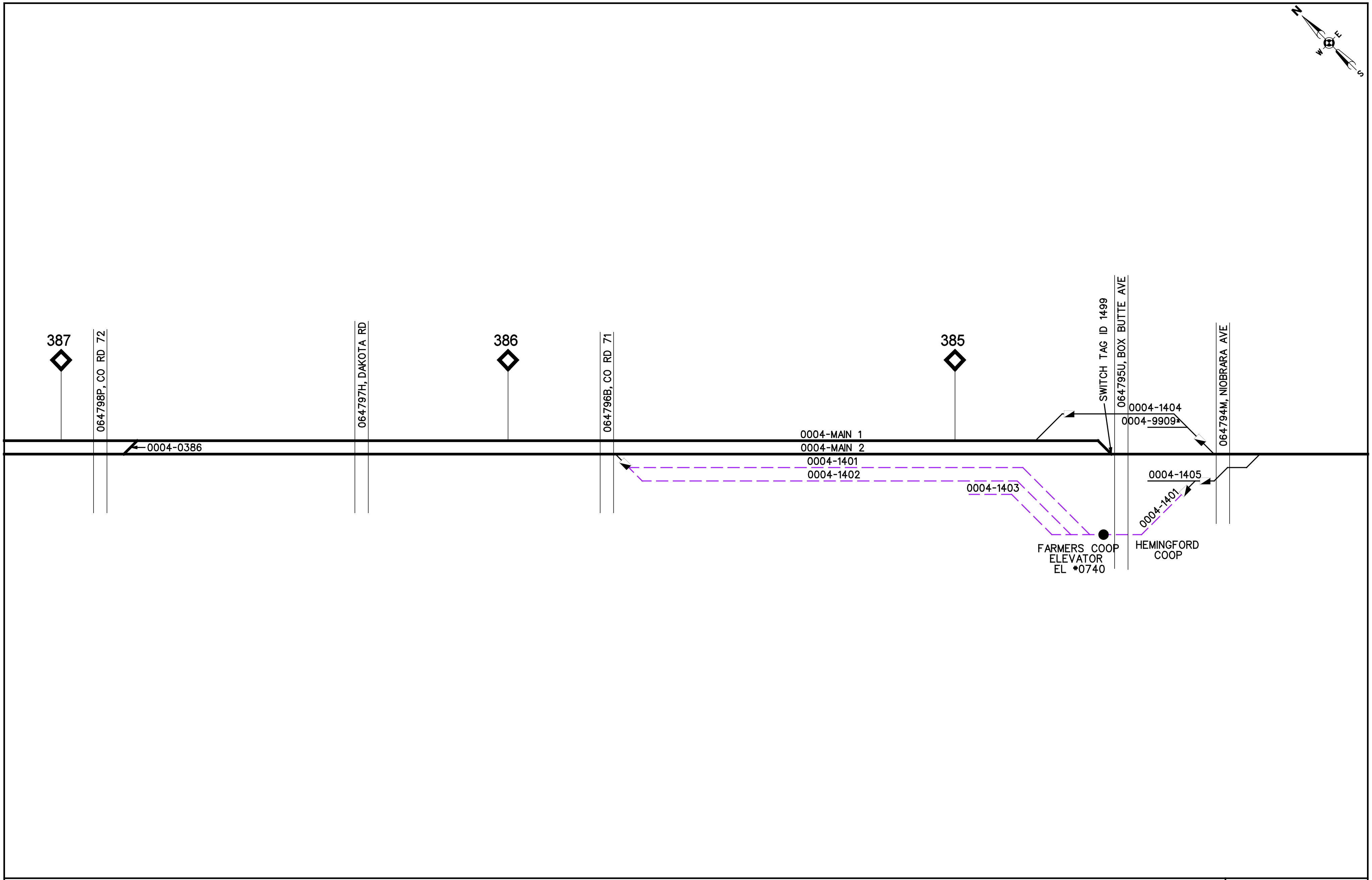
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 11, 2018

HEMINGFORD, NE
Butte Subdivision

← Edgemont, SD

East Alliance, NE →



BNSF RAILWAY

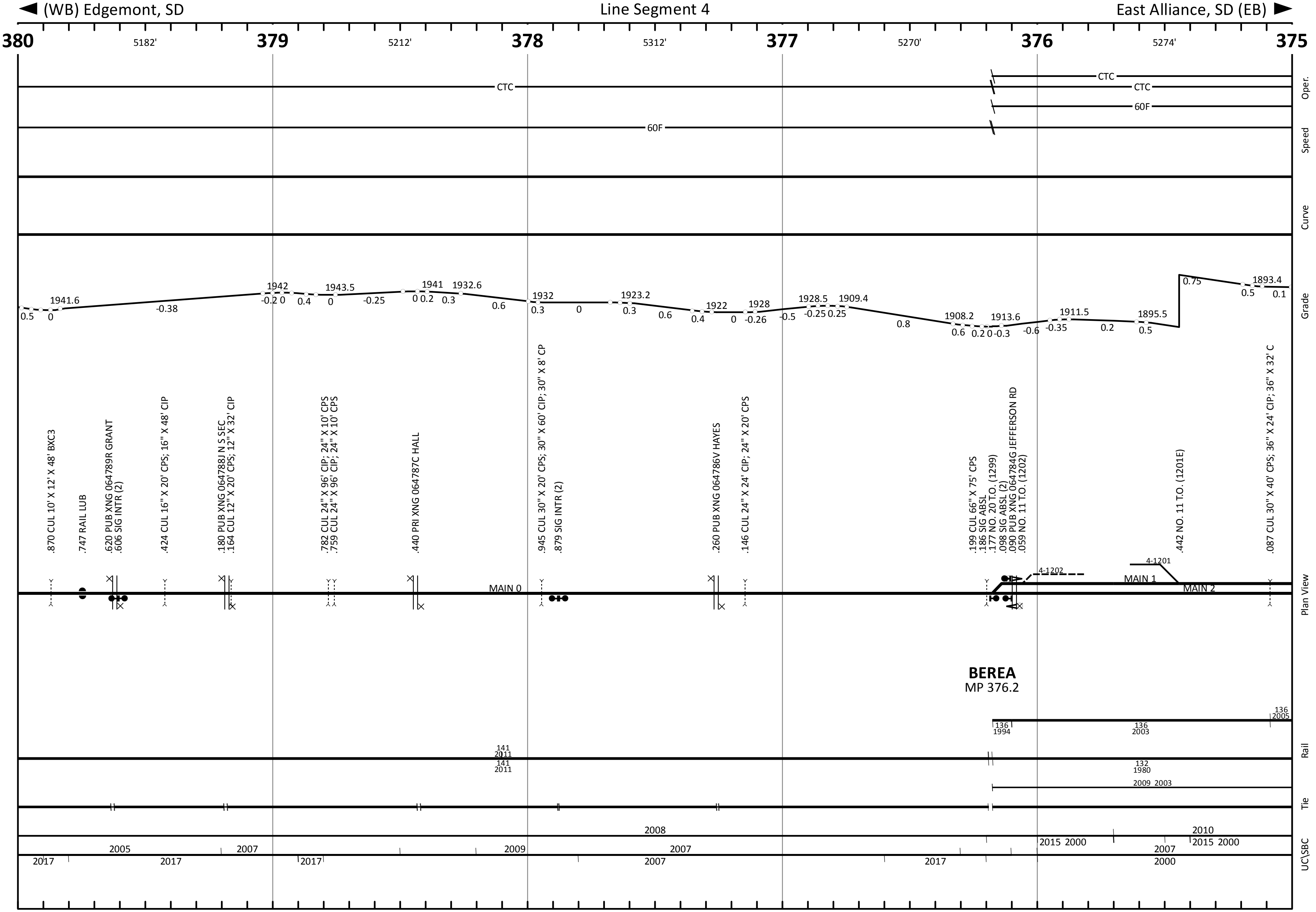
TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
SPECIAL CONDITIONS (ITEM *7)
FOR ADDITIONAL QUESTIONS ON PHYSICAL CHARACTERISTICS, CONTACT A LOCAL DIVISION MANAGER
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: HEMING
FSAC: 30383
REVISED: 11/5/2014
TEAM: HEMI14025.DGN
TRK CHT: BUT030.DGN
TEAM PG 025



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

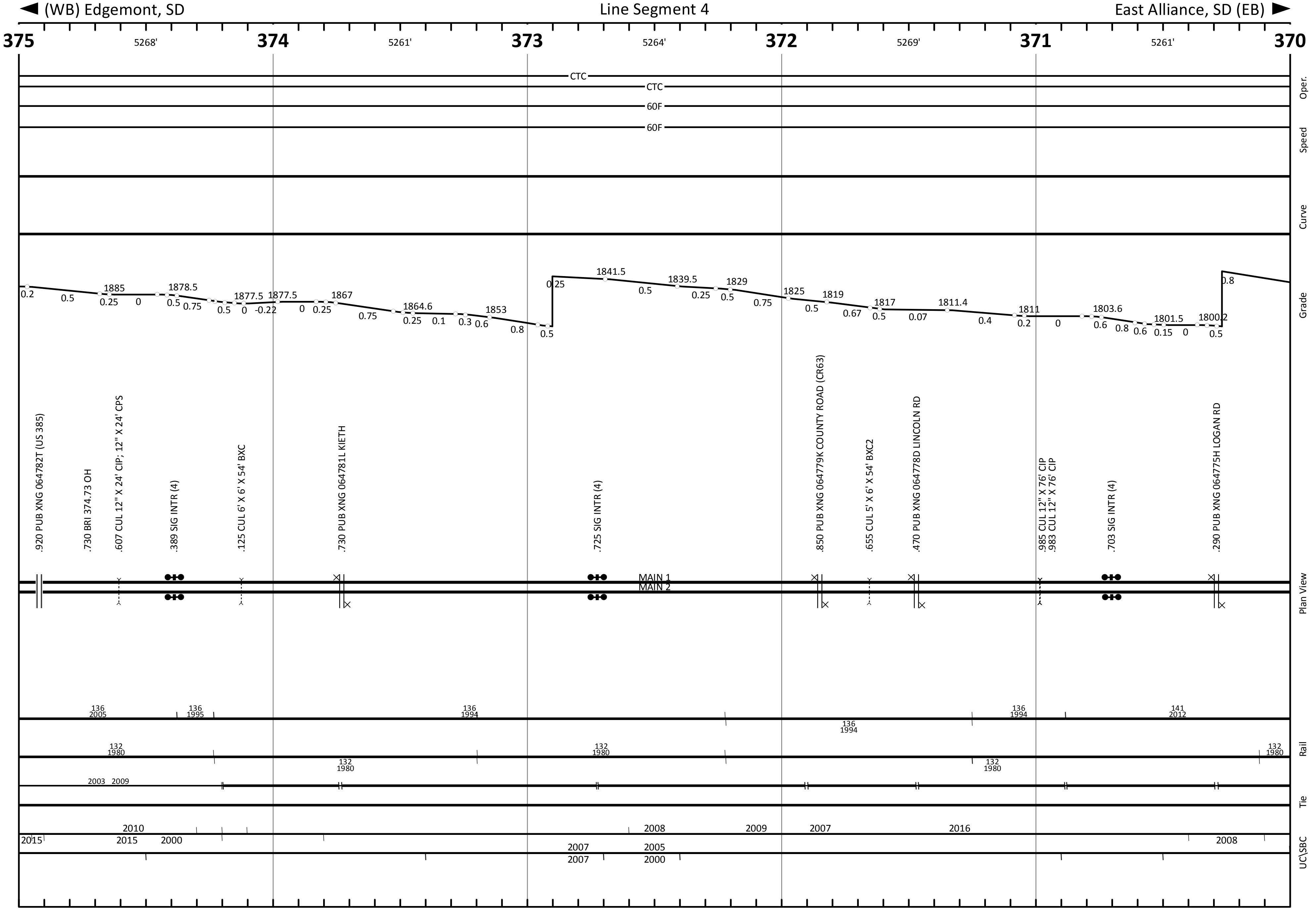
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



System Maintenance and Planning

Butte Subdivision

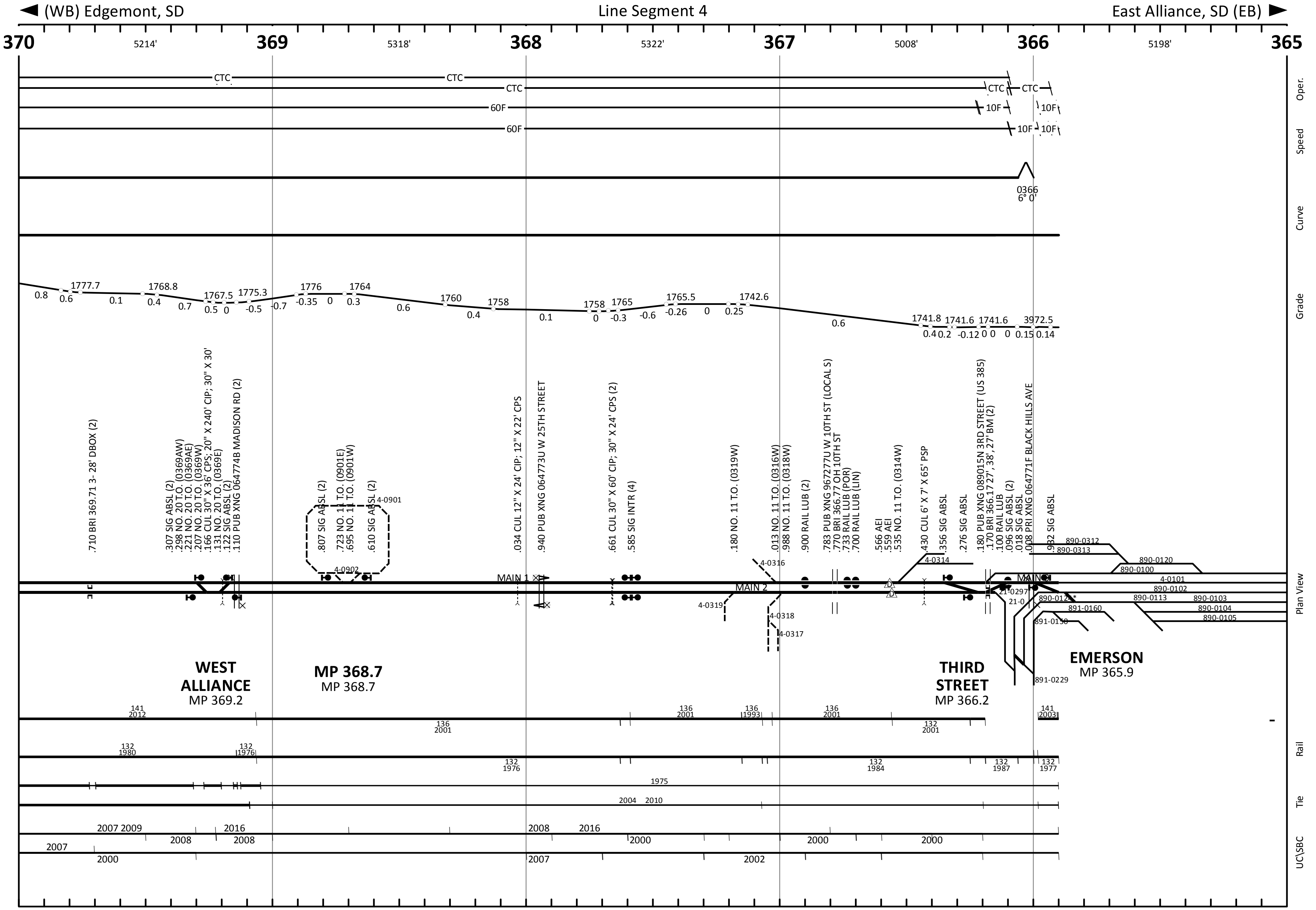
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



BNSF RAILWAY

System Maintenance and Planning

Butte Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

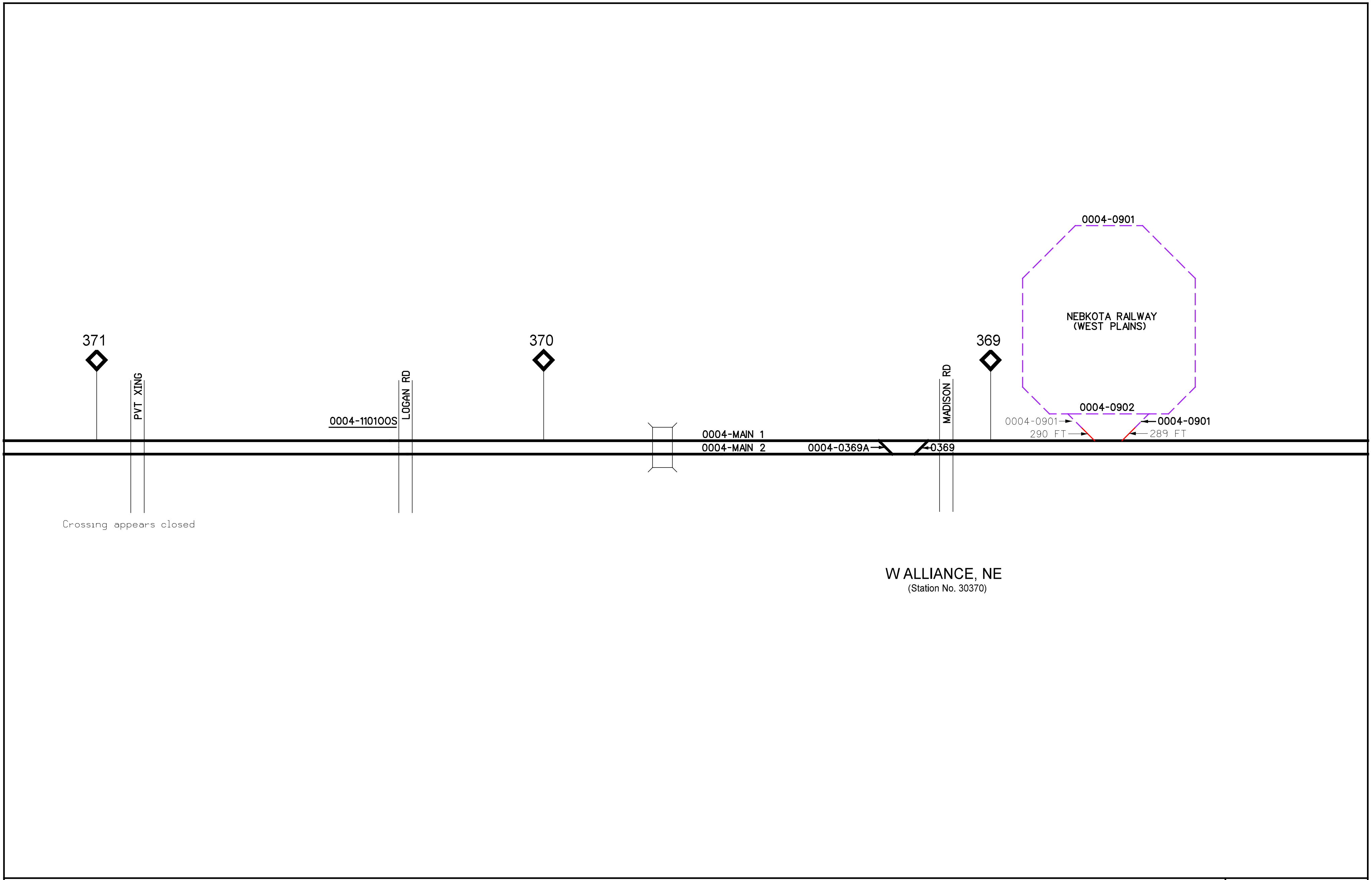
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

← Edgemont, SD

GINN, NE - Butte Subdivision

East Alliance, NE →



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IND OWNED & MAINT
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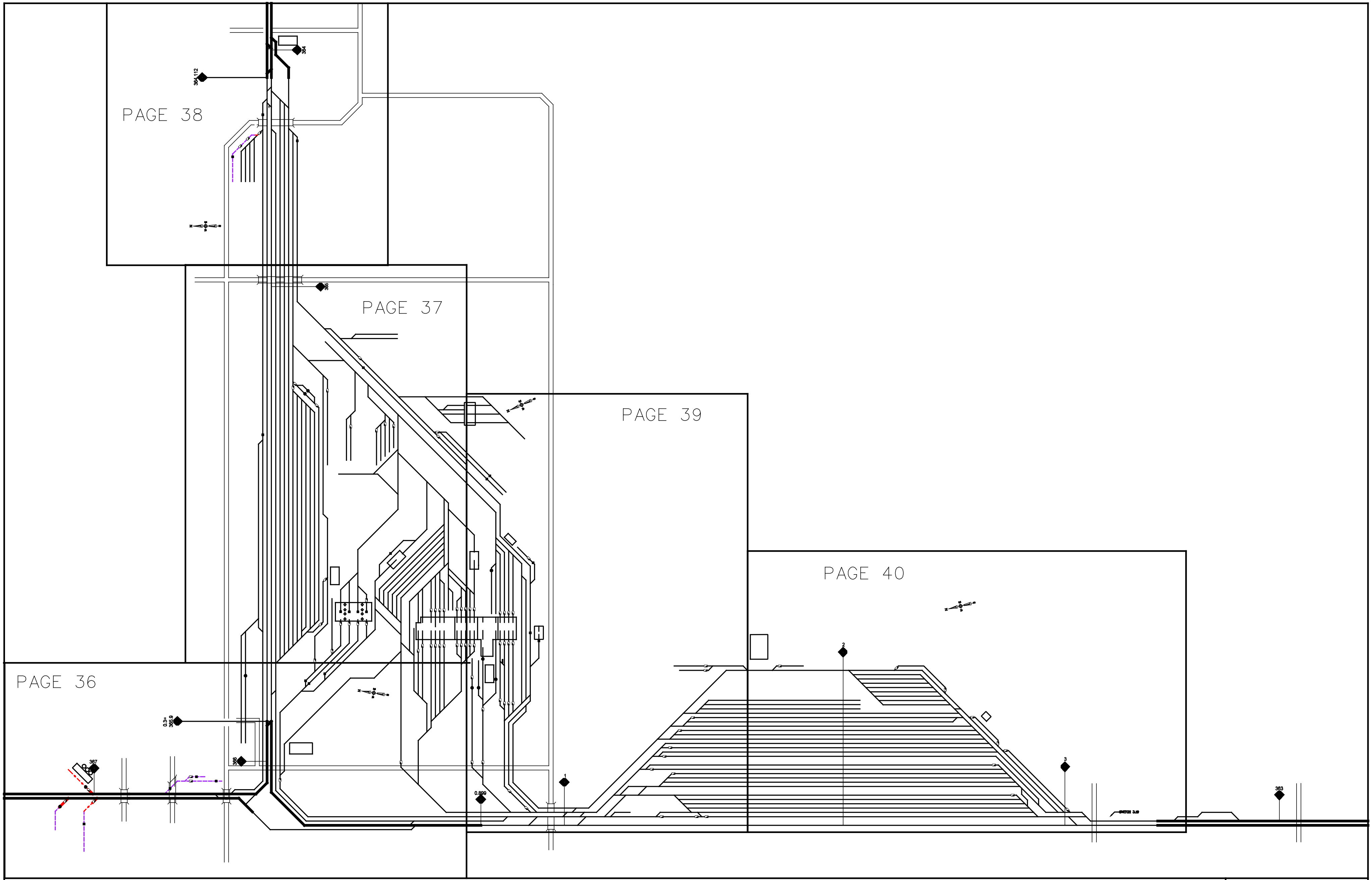
◪ DERAIL
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: GINN
FSAC: 30369
REVISED: 12/12/2016
TEAM: GINN03031.DGN
TRK CHT: BUT034.DGN
TEAM PG 031

ALLIANCE, NE
Butte Subdivision

← Edgemont, SD   Sterling, CO →



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▬	TRACKAGE RIGHTS
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IF PURPLE OTHERS MAINTAIN (NOT BNSF)
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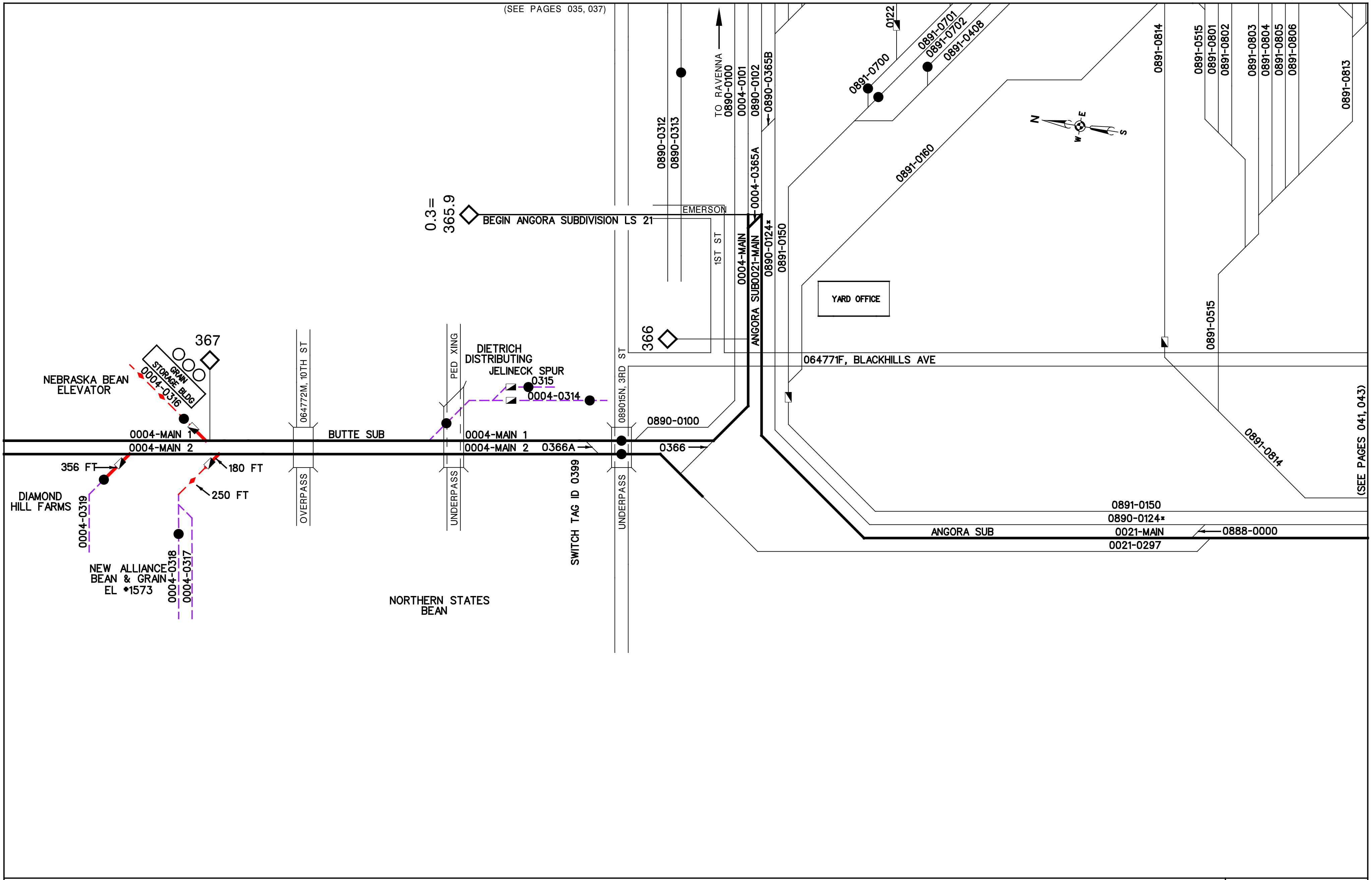
STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/27/2016
TEAM: *********.DGN
TRK CHT: BUT035.DGN
TEAM PG ###

ALLIANCE, NE
Butte Subdivision

← Edgemont, SD

Sterling, CO →



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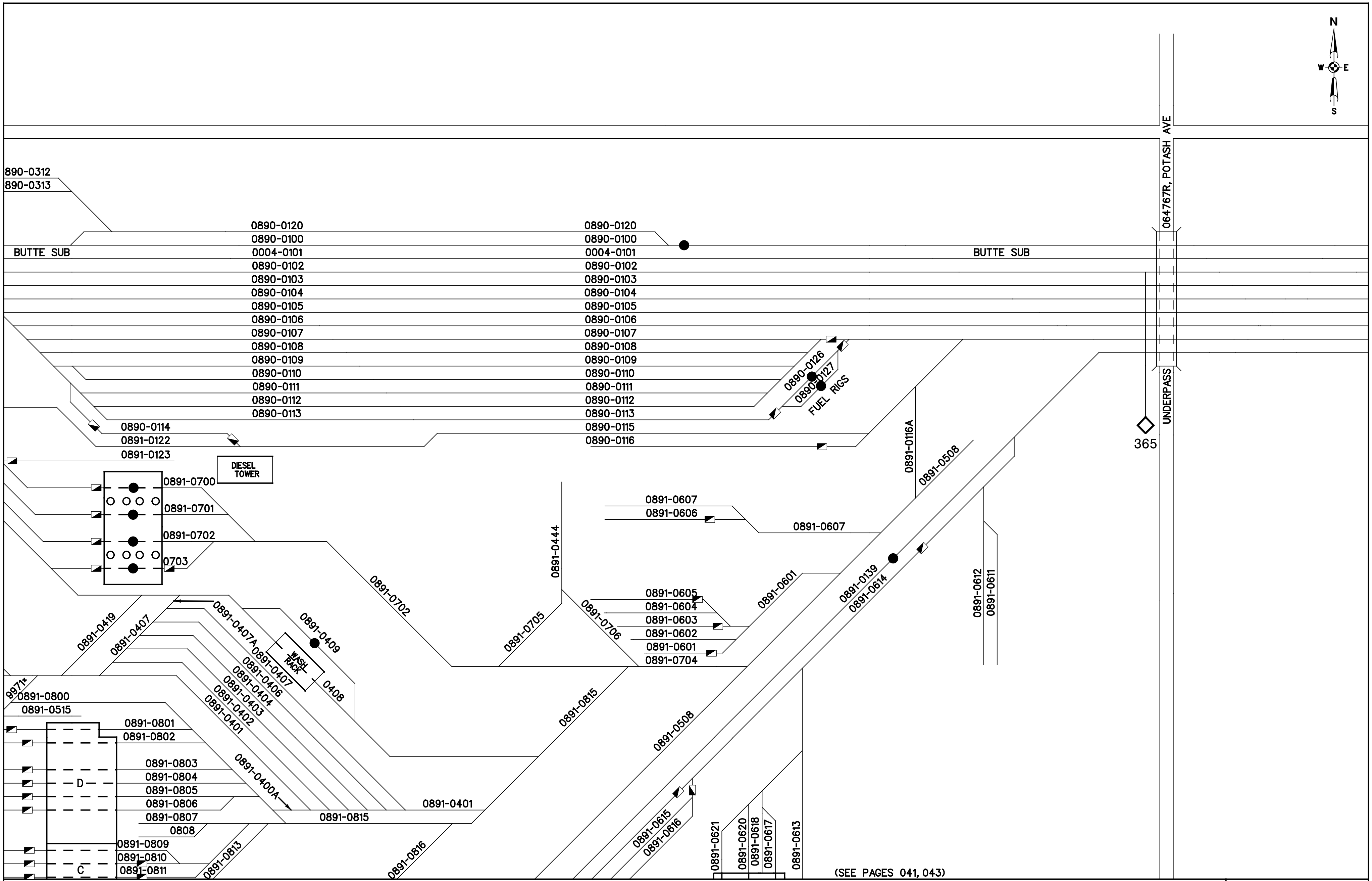
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 6/6/2018
TEAM: ALLI01033.DGN
TRK CHT: BUT036.DGN

ALLIANCE, NE
Butte Subdivision

◄ Edgemont, SD

Ravenna, NE ►



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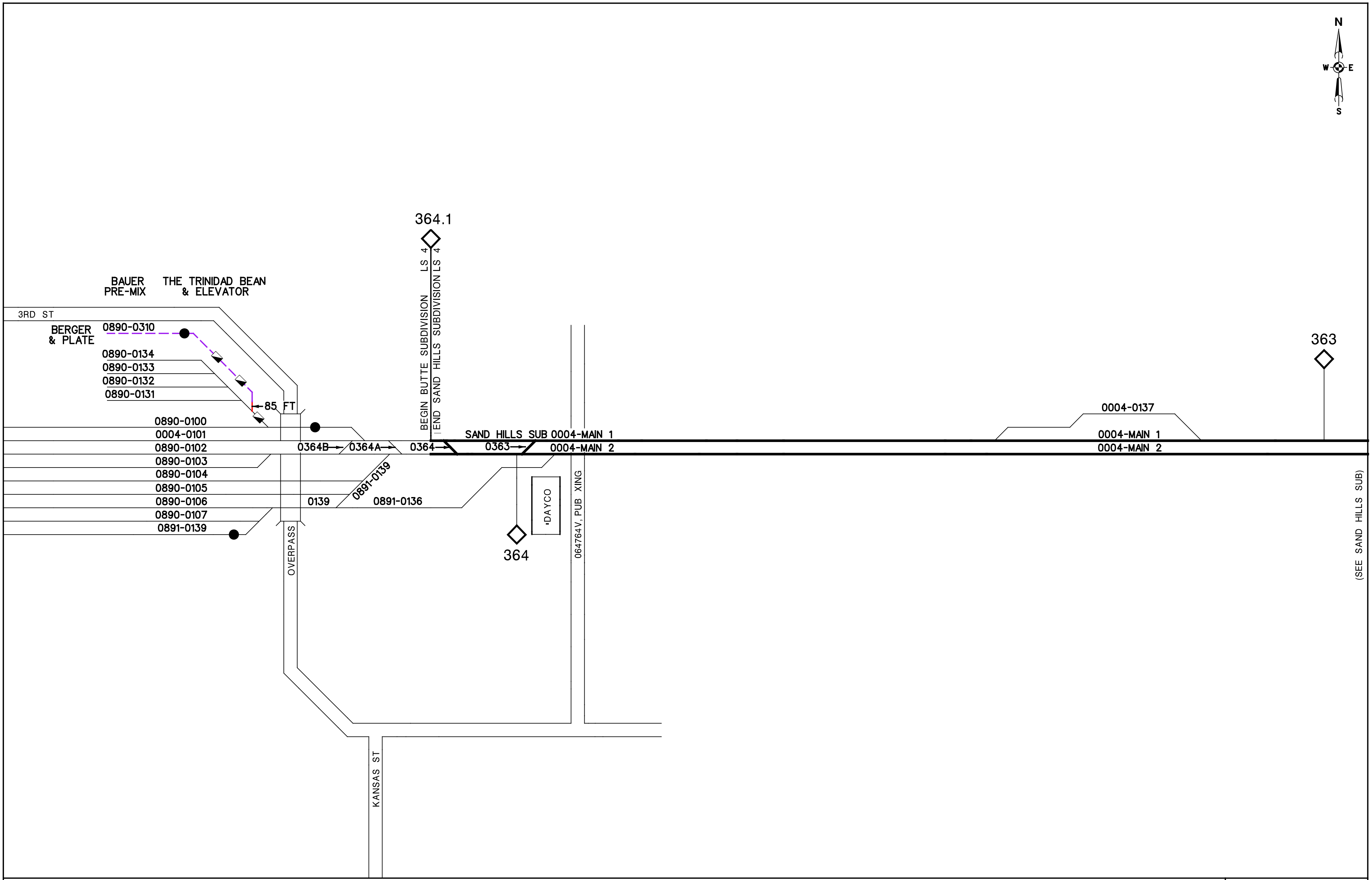
STATION ABBR: ALLINE
FSAC: 30364
REVISED: 11/1/2017
TEAM: ALLI01035.DGN
TRK CHT: BUT037.DGN
TEAM PG 035

ALLIANCE, NE
Butte Subdivision

← Edgemont, SD

Ravenna, NE →



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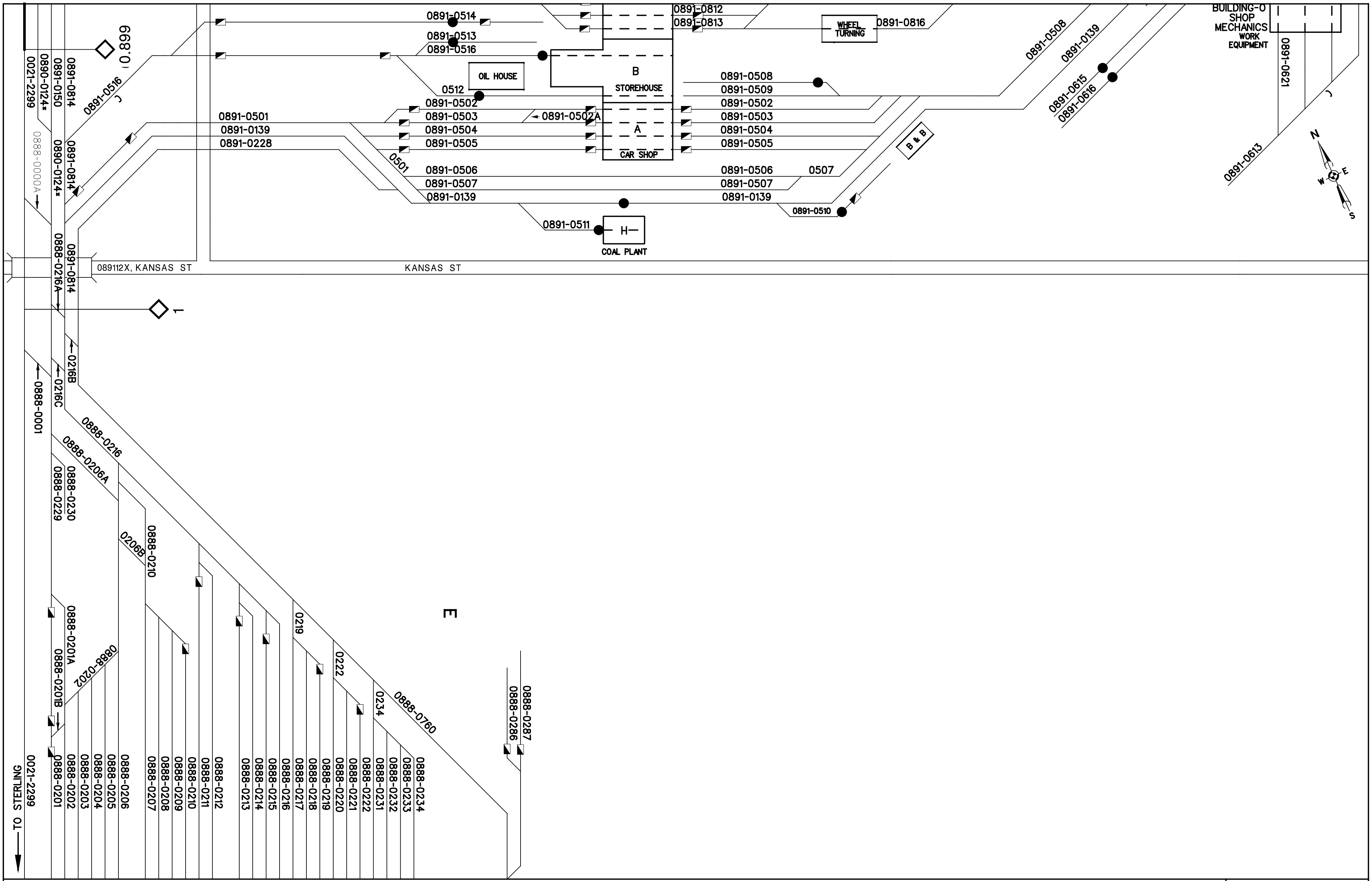
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 11/1/2017
TEAM: ALLI01039.DGN
TRK CHT: BUT038.DGN
TEAM PG 039

ALLIANCE, NE
Butte Subdivision



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─◆─	INDUSTRY OWNED & BNSF MAINT	━━	TRACKAGE RIGHTS
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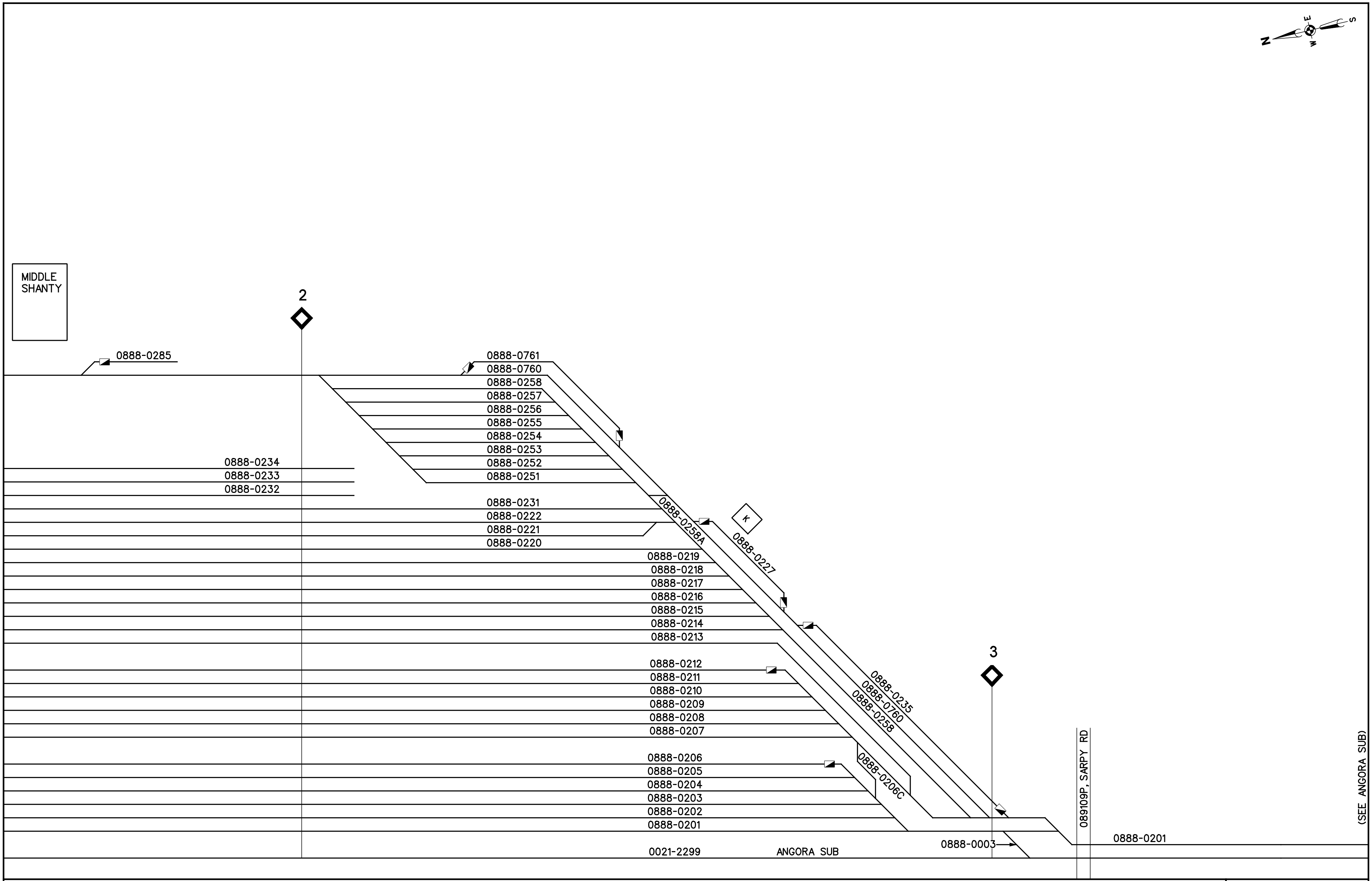
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 11/1/2017
TEAM: ALLI01041.DGN
TRK CHT: BUT039.DGN
TEAM PG 041

← Edgemont, SD

ALLIANCE, NE - Butte Subdivision

Sterling, CO →



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STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/29/2016
TEAM: ALLI02045.DGN
TRK CHT: BUT040.DGN

◄ (WB) Edgemont, SD Line Segment 4 East Alliance, SD (EB) ►

BNSF RAILWAY

Track Chart
Canyon Subdivision

East Guernsey, WY to Bridger Jct., WY

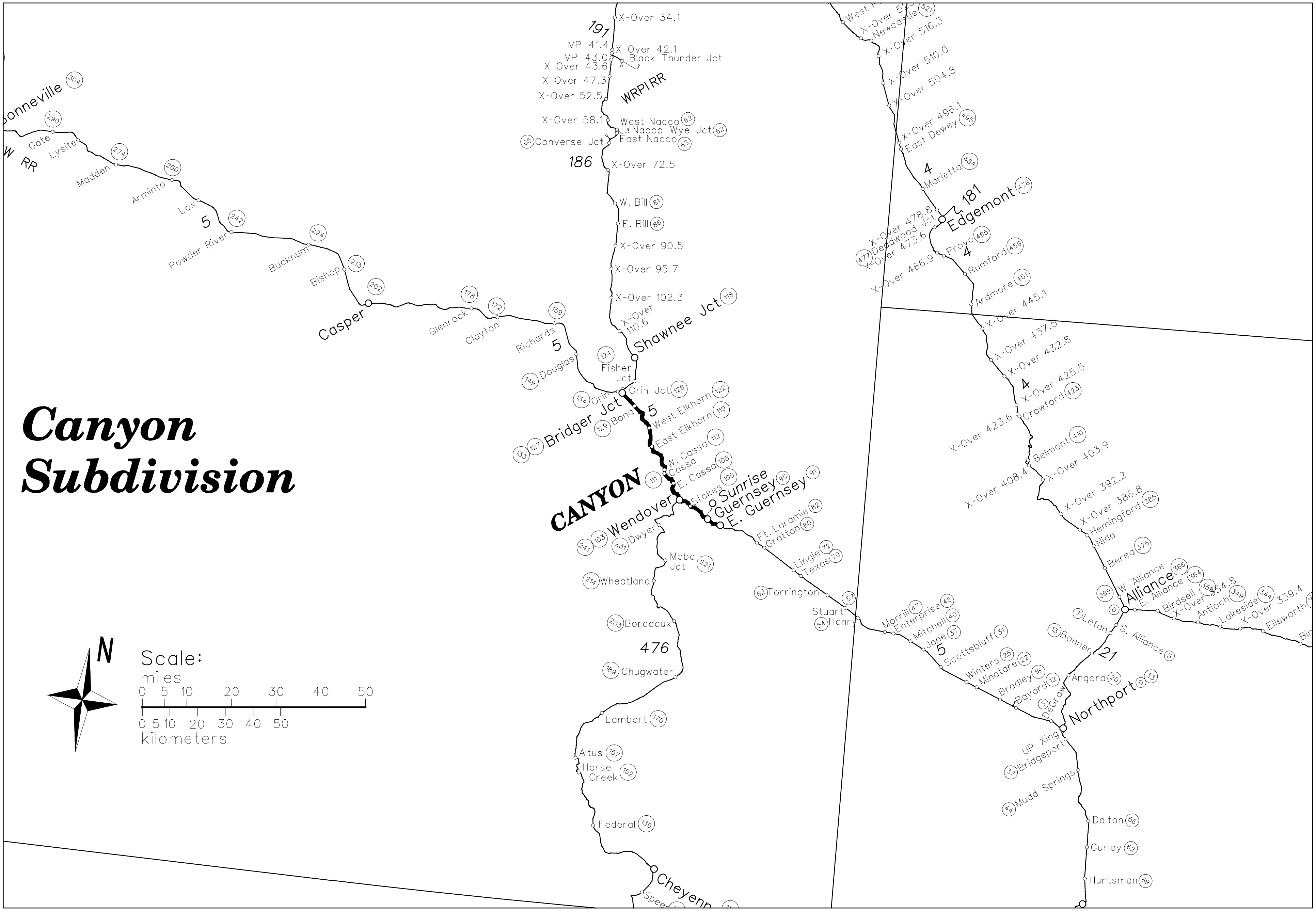
MP 90.4 to MP 133.2

See each page for latest revised date.

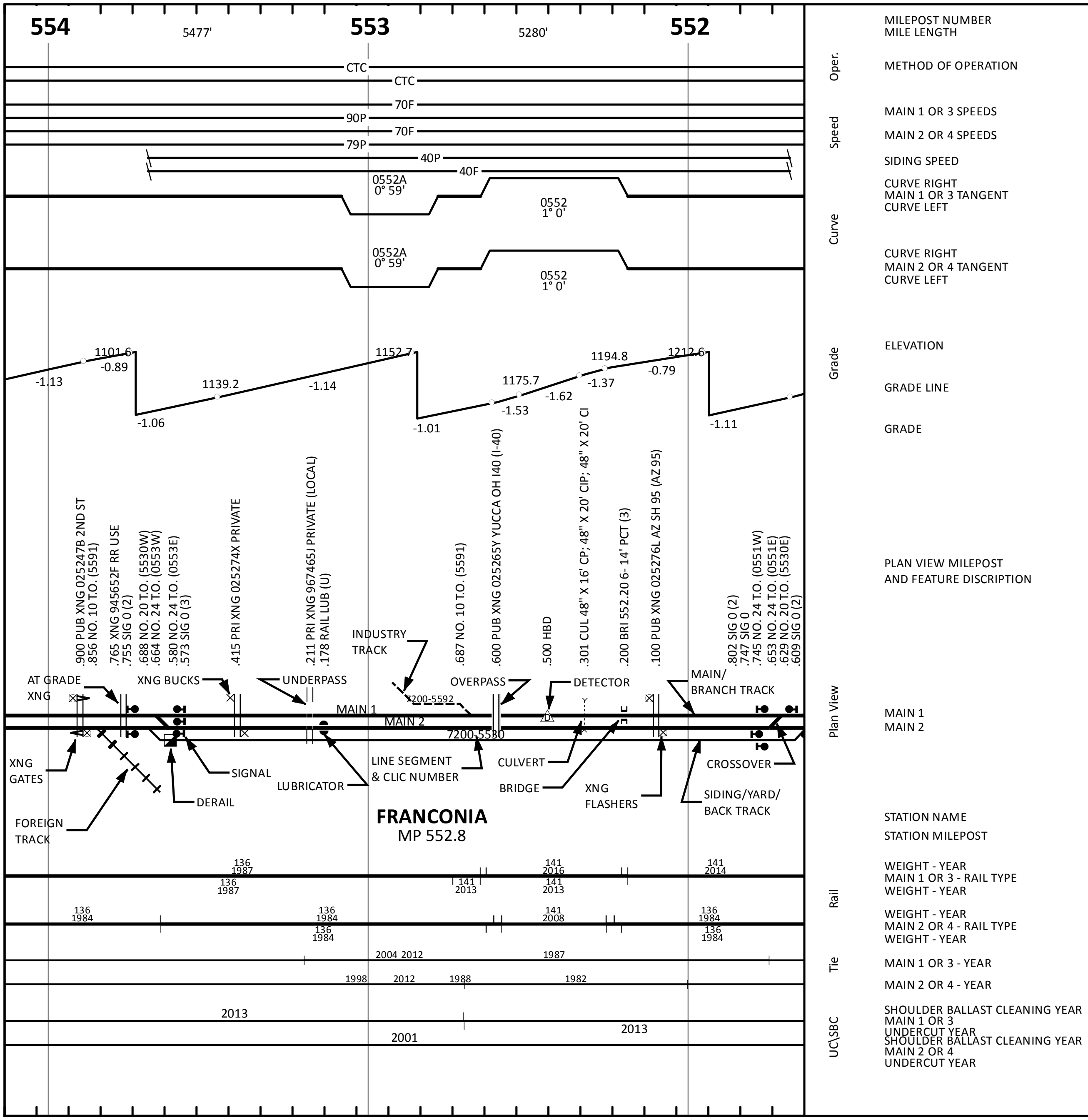
Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Canyon Subdivision



TRACK CHART FEATURE LEGEND



NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280')   VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

FILE: Y:\drawings\trkchrts\ASTC\MXD_Files\TC_Legend.mxd

Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

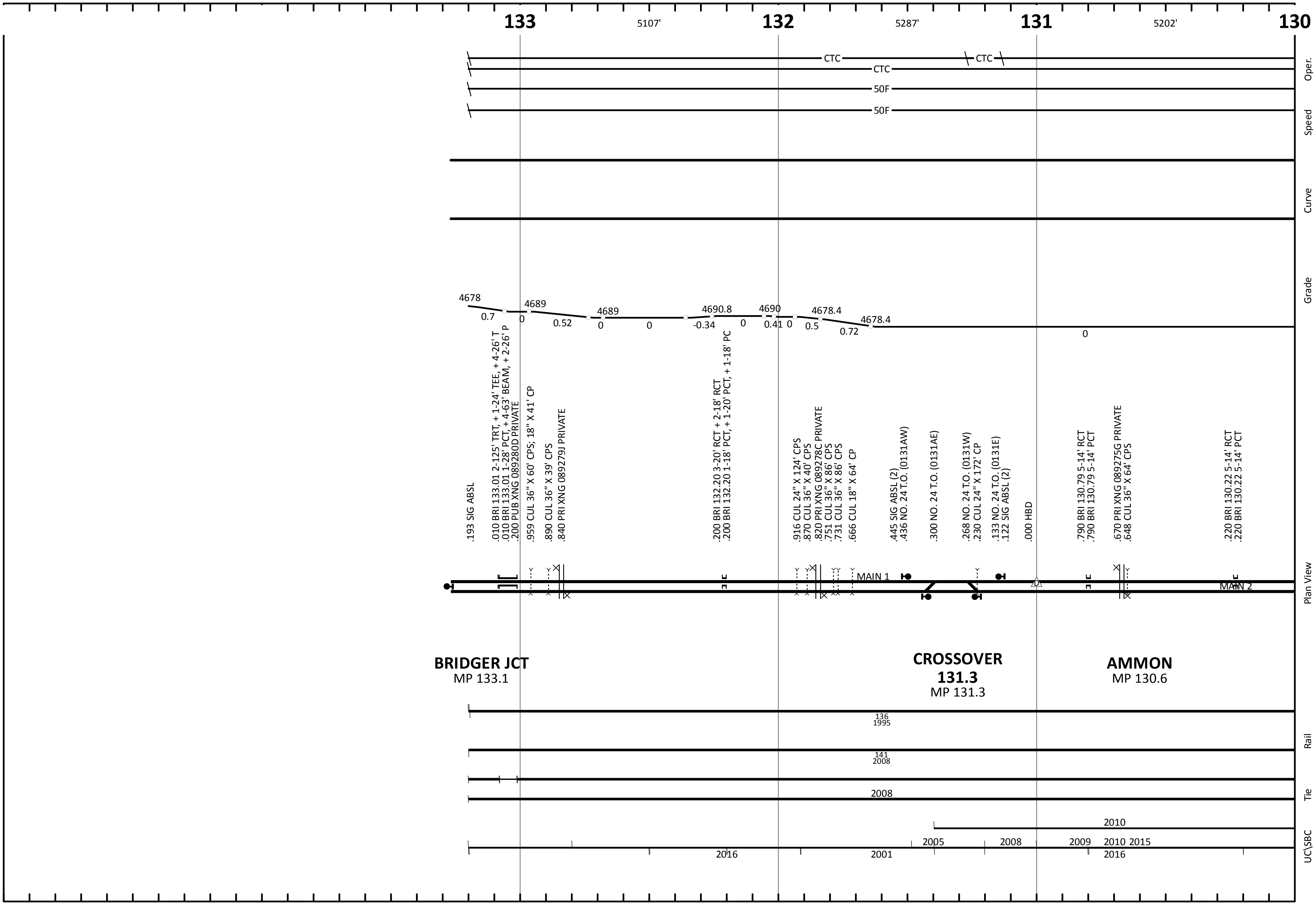
Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL

◄ (WB) Bridger Jct., WY Line Segment 5 East Guernsey, WY (EB) ►



BNSF RAILWAY
System Maintenance and Planning

Canyon Subdivision
Powder River Operating Division
Powder River West Engineering Division

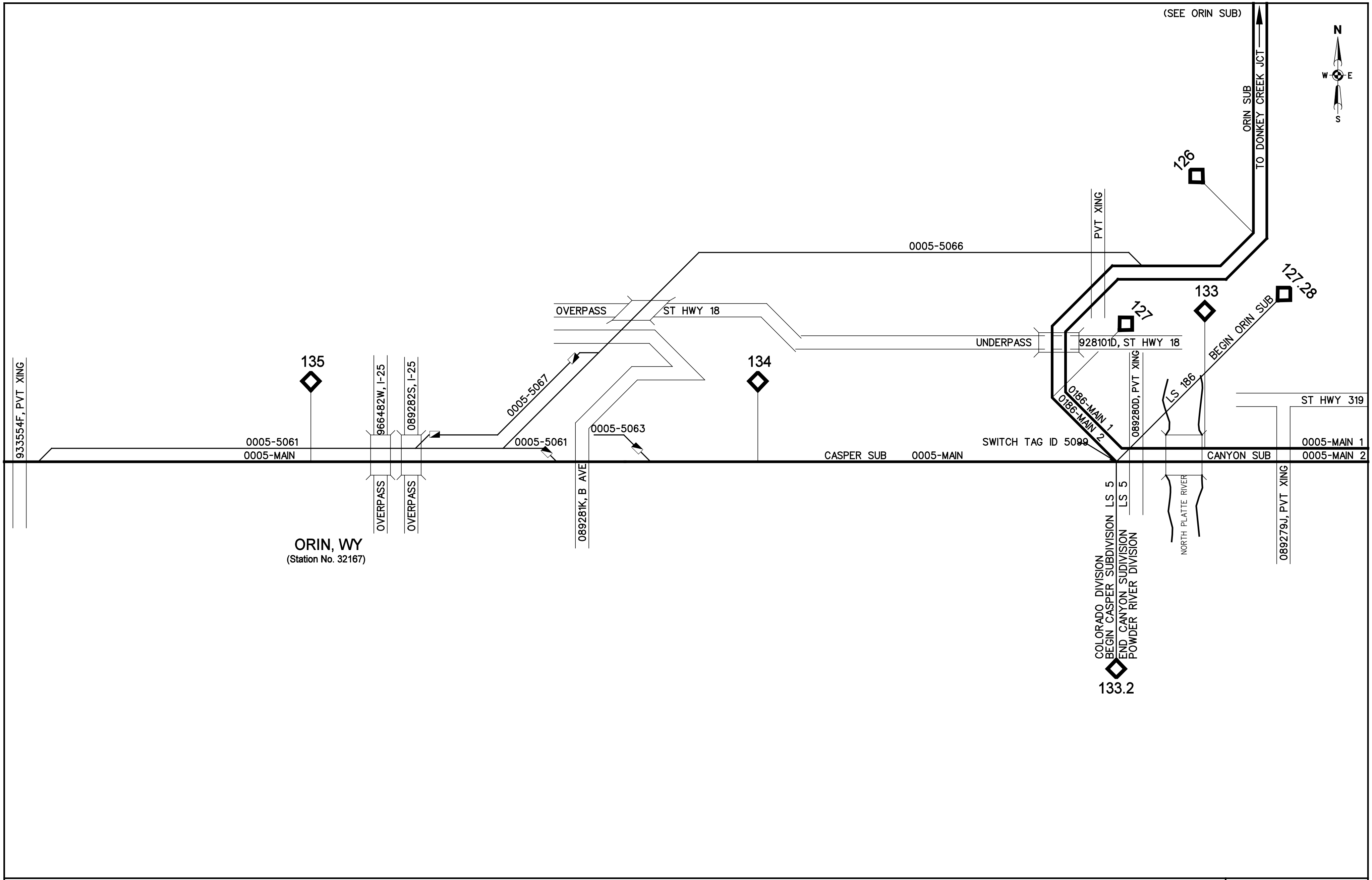
Engineering Track Chart
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 11, 2018

BRIDGER JCT, WY

Orin Subdivision

← Laurel, MT

East Guernsey, WY →



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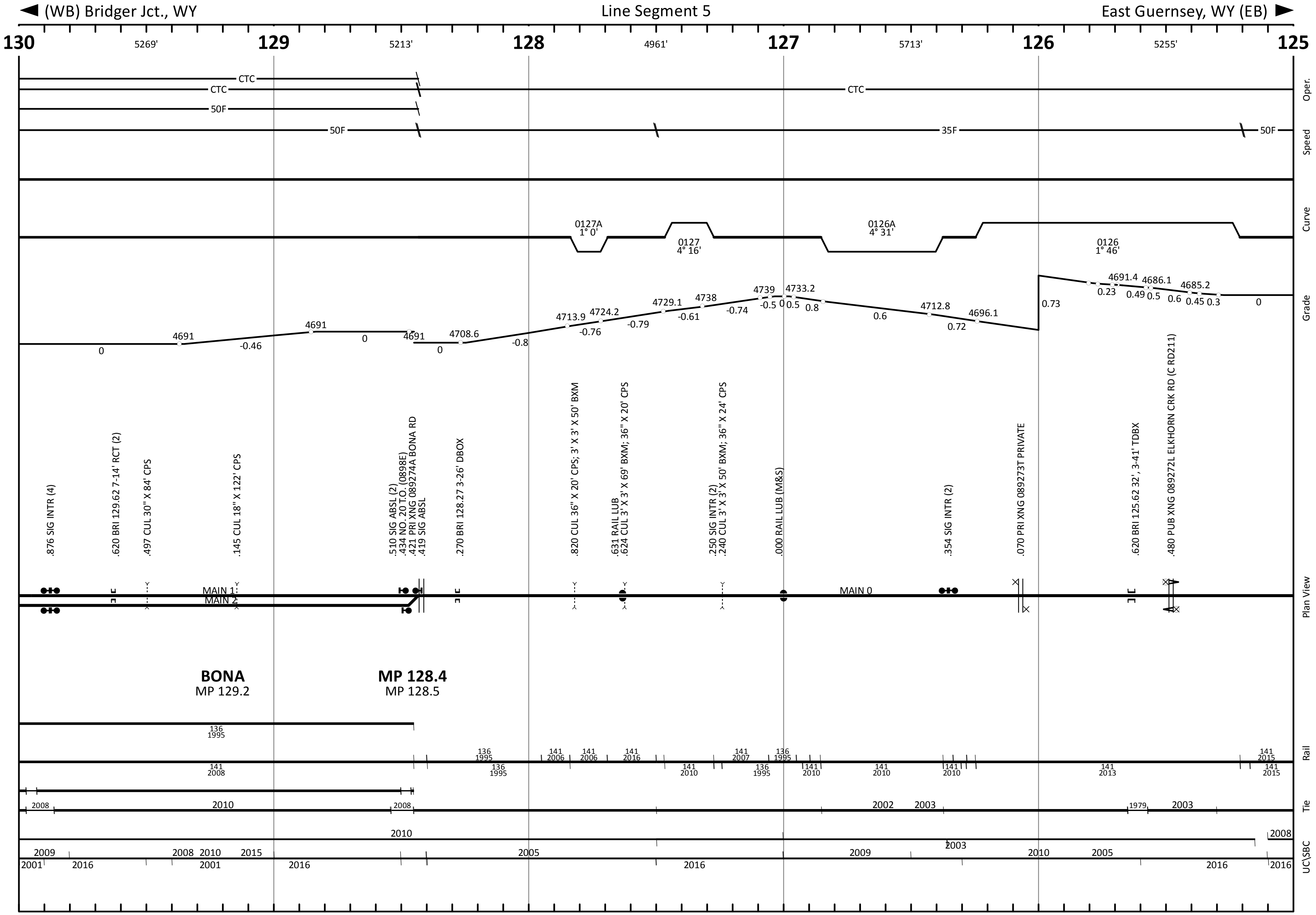
——	TRACKAGE RIGHTS
┼┼┼┼	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: BRIJWY
FSAC: 32166
REVISED: 12/5/2016
TEAM:BRID50003.DGN
TRK CHT: CAN006.dgn



BNSF RAILWAY

System Maintenance and Planning

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Powder River West Engineering Division

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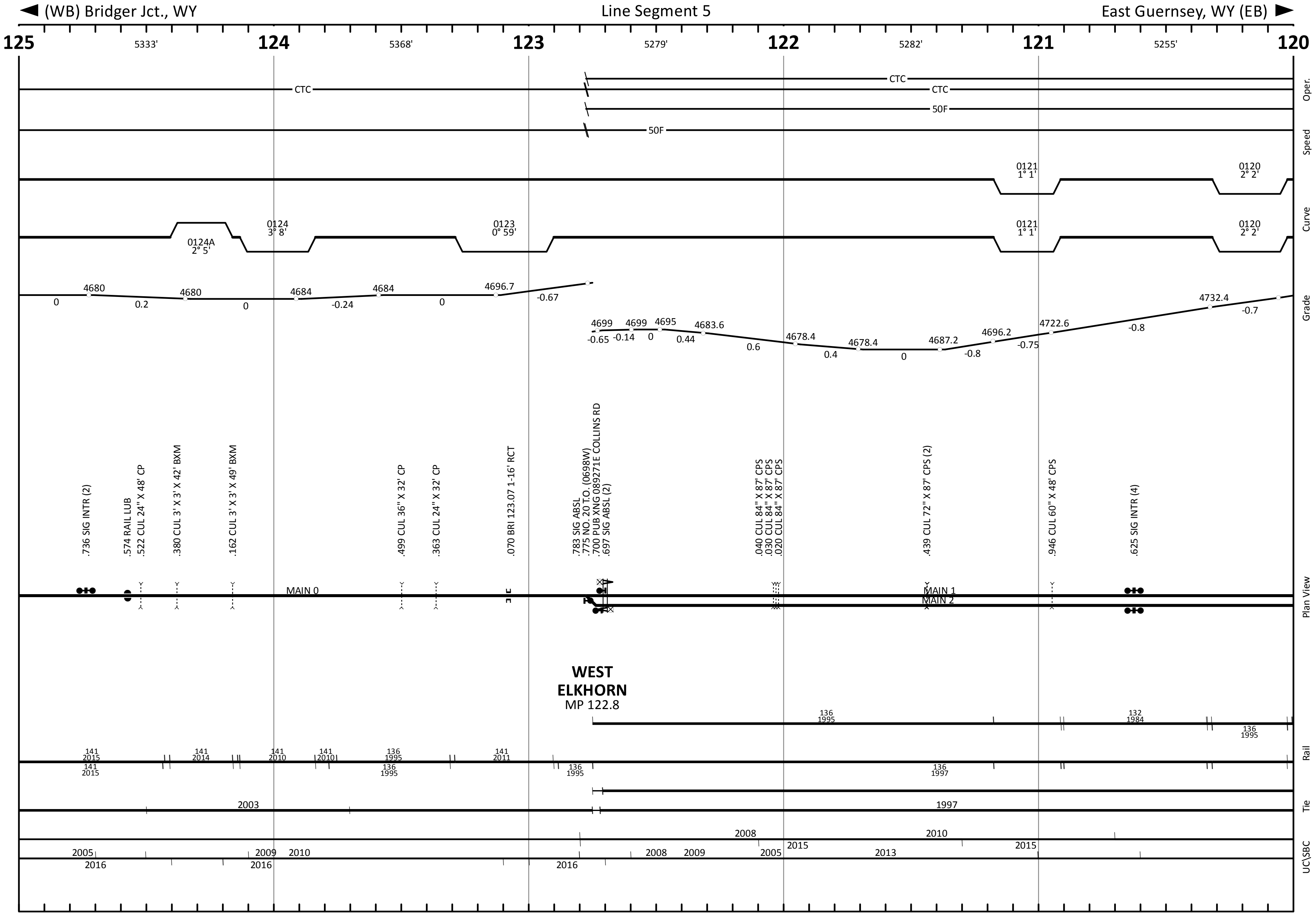
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018



BNSF RAILWAY

System Maintenance and Planning

Canyon Subdivision

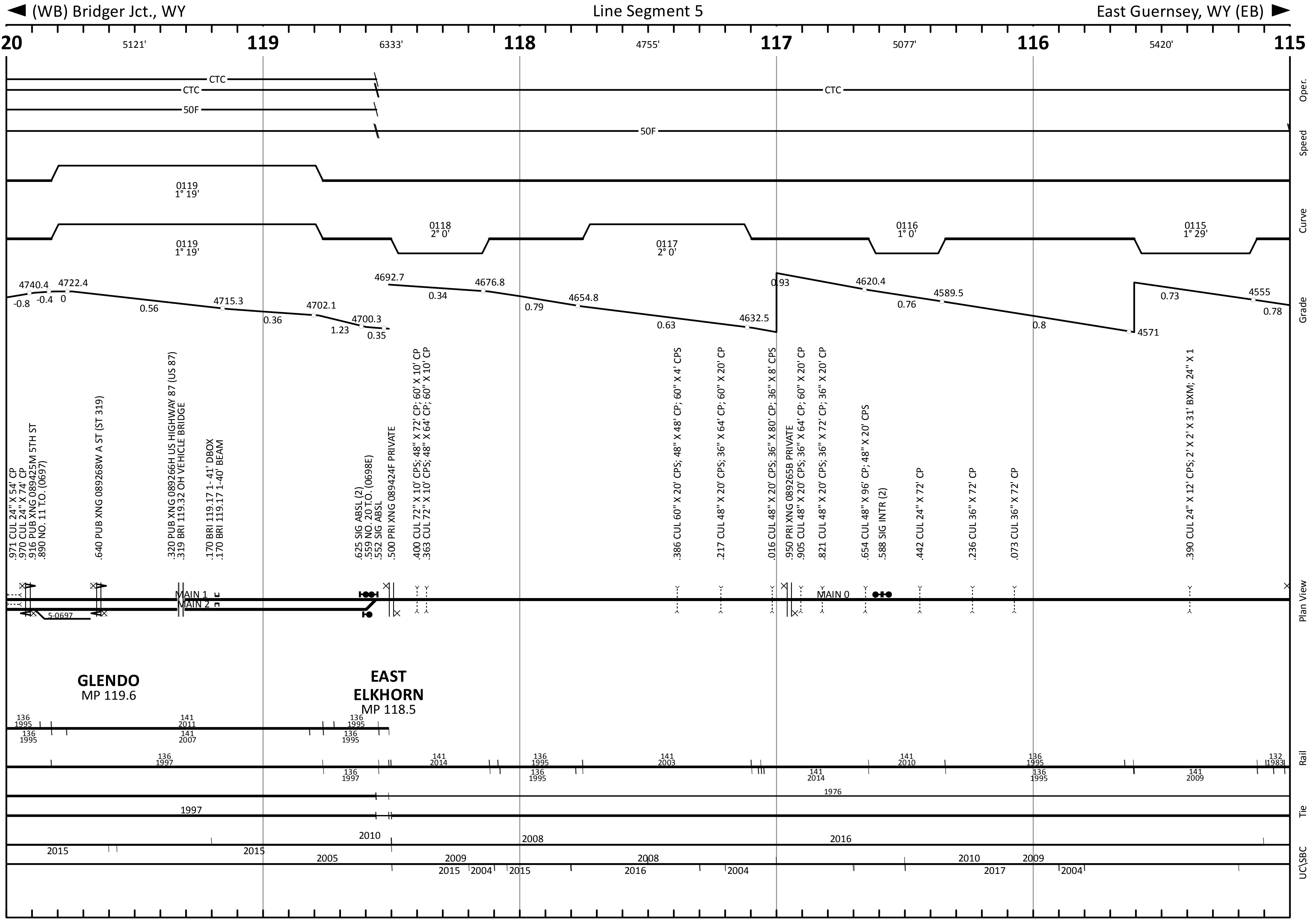
Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018 Page 8 of 20



BNSF RAILWAY

System Maintenance and Planning

Canyon Subdivision

Powder River Operating Division
Powder River West Engineering Division

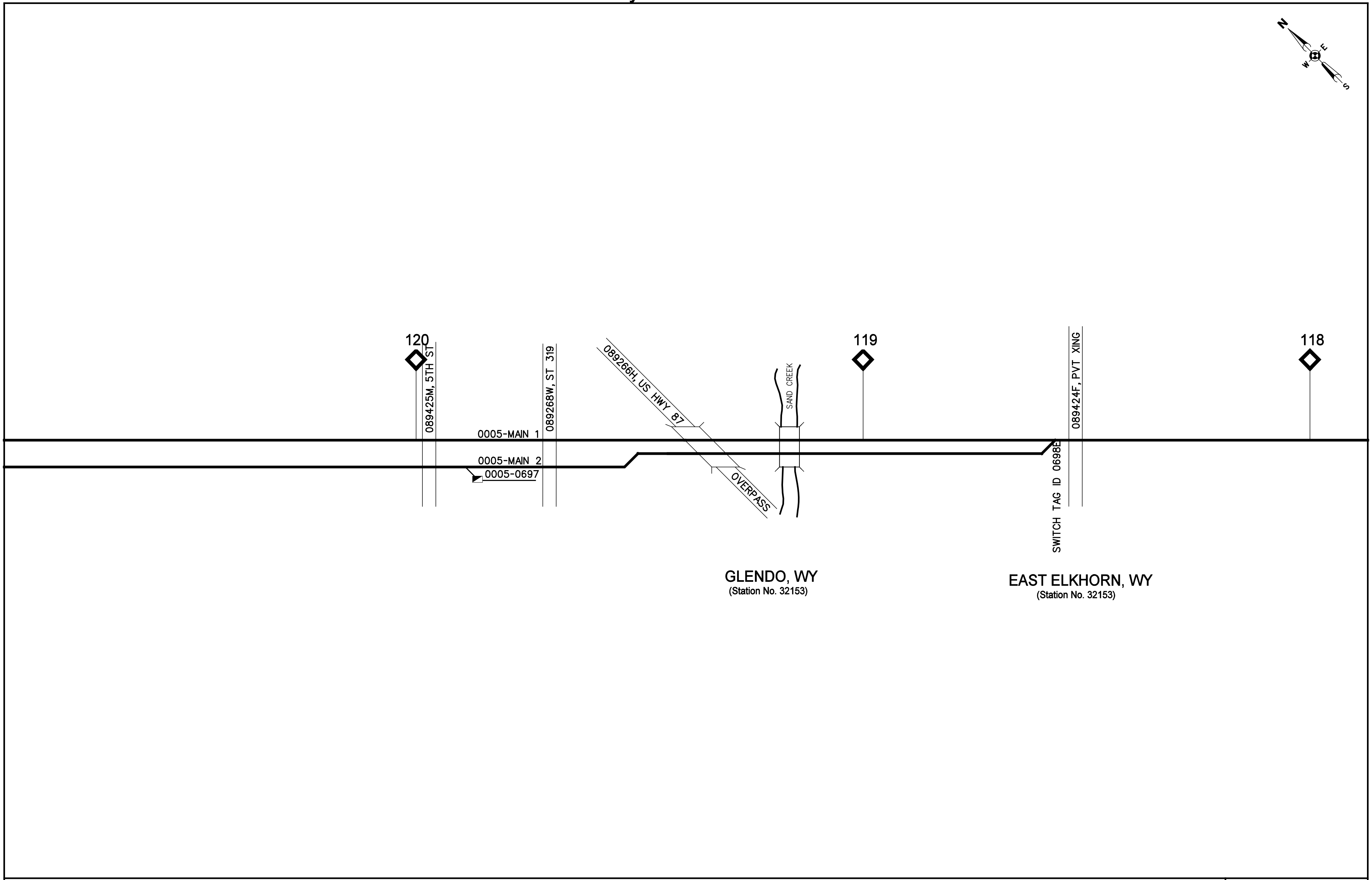
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 11, 2018

GLENDO, WY
Canyon Subdivision

◄ Bridger Jct., WY

East Guernsey WY ►



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
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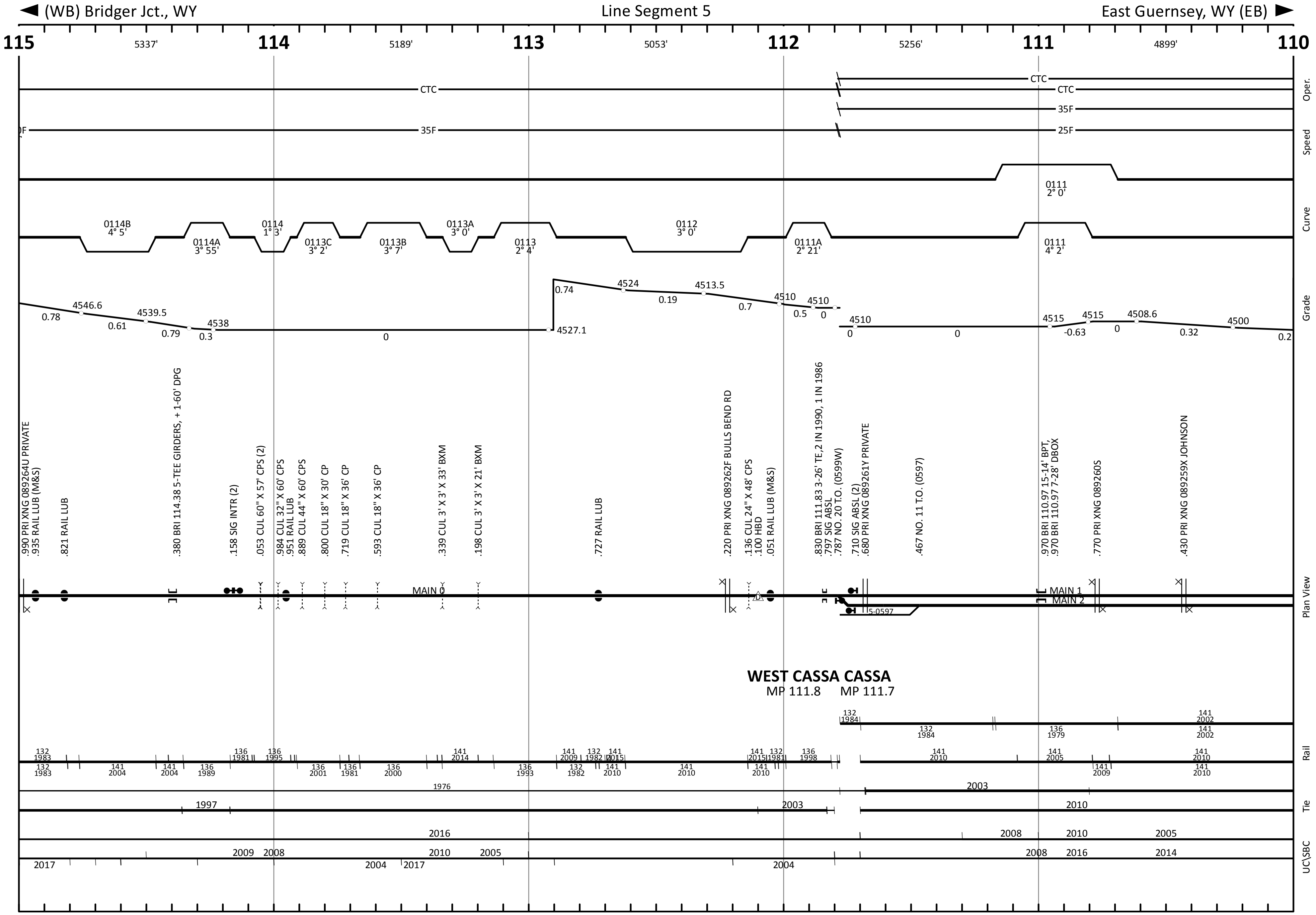
FOR ADDITIONAL QUESTIONS ON PHYSICAL CHARACTERISTICS, CONTACT A LOCAL DIVISION MANAGER
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: GLENWY
FSAC: 32153
REVISED: 6/30/2015
TEAM: GLEN06005.DGN
TRK CHT: CAN010.dgn



BNSF RAILWAY

System Maintenance and Planning

Canyon Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

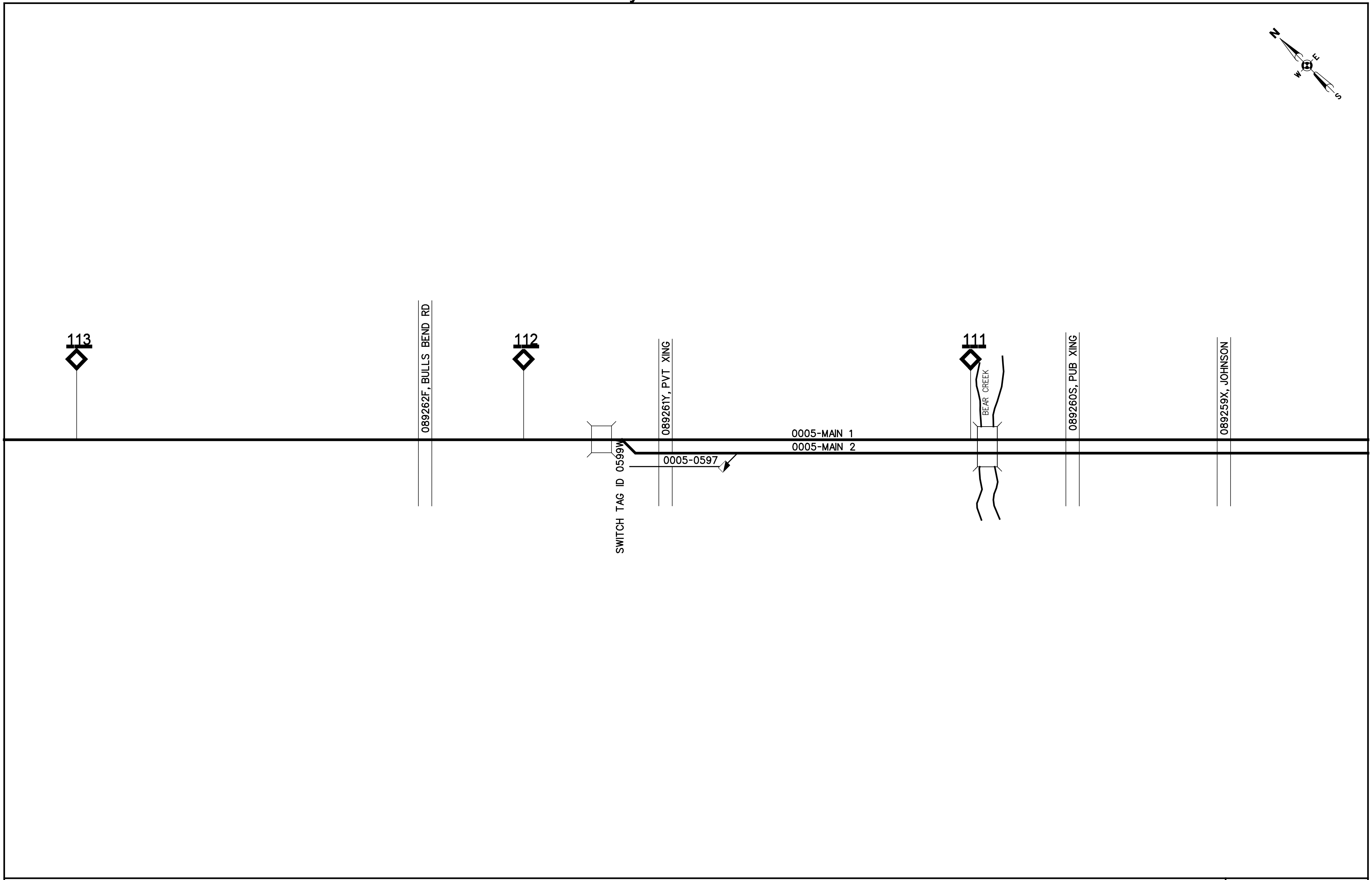
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

CASSA, WY
Canyon Subdivision

← Bridger Jct., WY

East Guernsey, WY →



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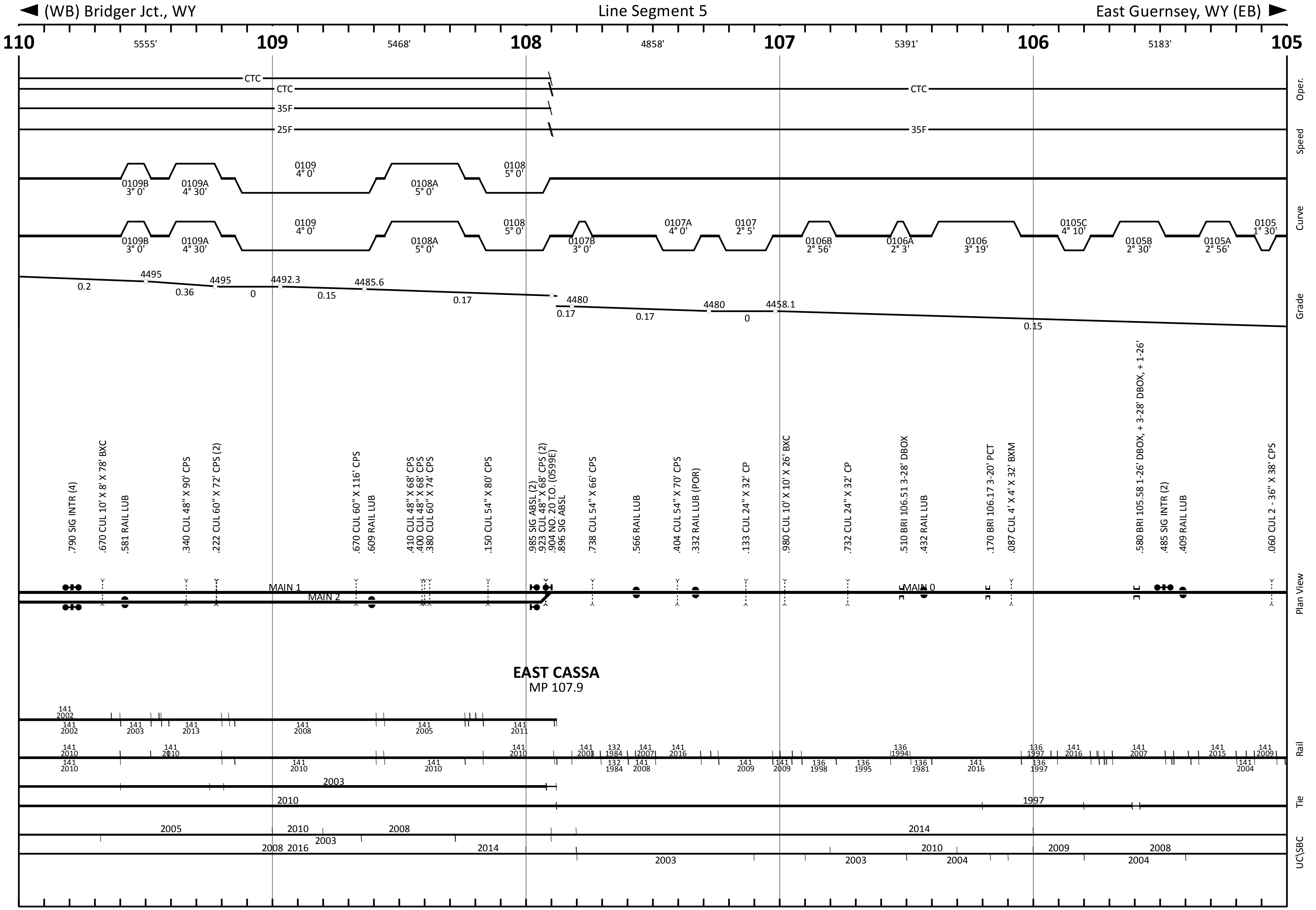
STATION ABBR: CASSA
FSAC: 32145
REVISED: 6/30/2015
TEAM: CASS05007.DGN
TRK CHT: CAN012.dgn
TEAM PG 007



BNSF RAILWAY

System Maintenance and Planning

Canyon Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

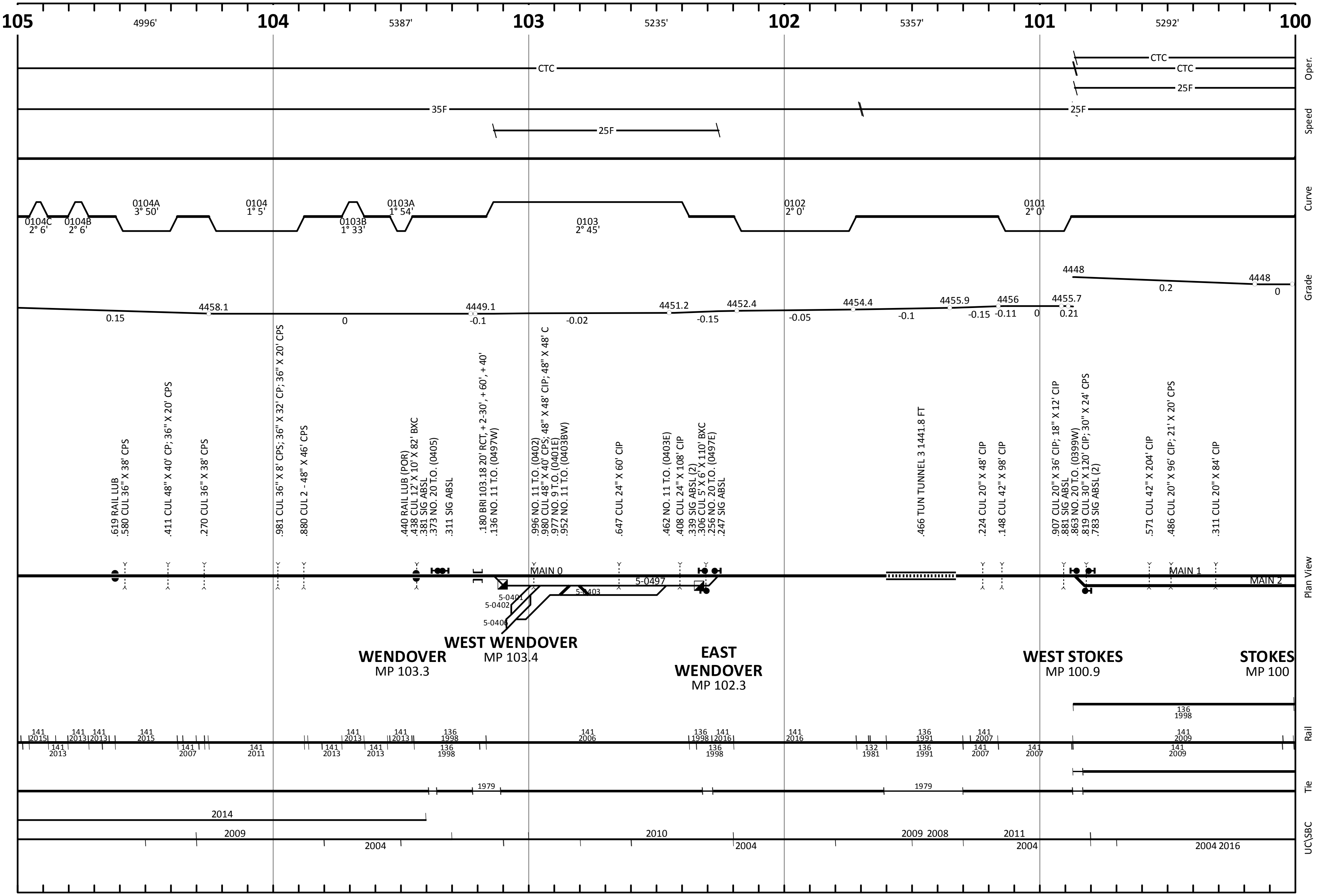
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

◄ (WB) Bridger Jct., WY

Line Segment 5

East Guernsey, WY (EB) ►



System Maintenance and Planning

Canyon Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

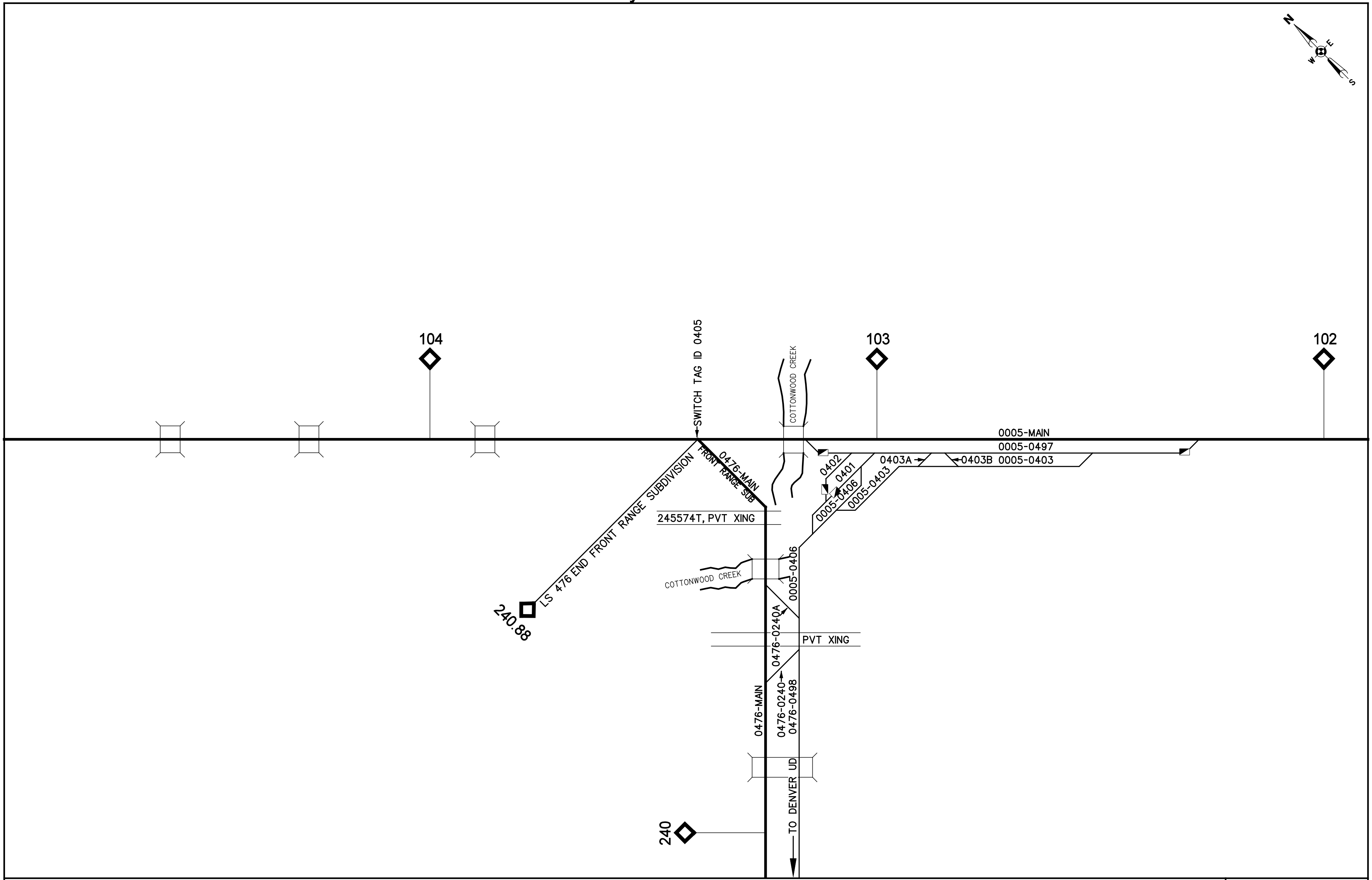
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

WENDOVER, WY
Canyon Subdivision

← Bridger Jct., WY

East Guernsey, WY →



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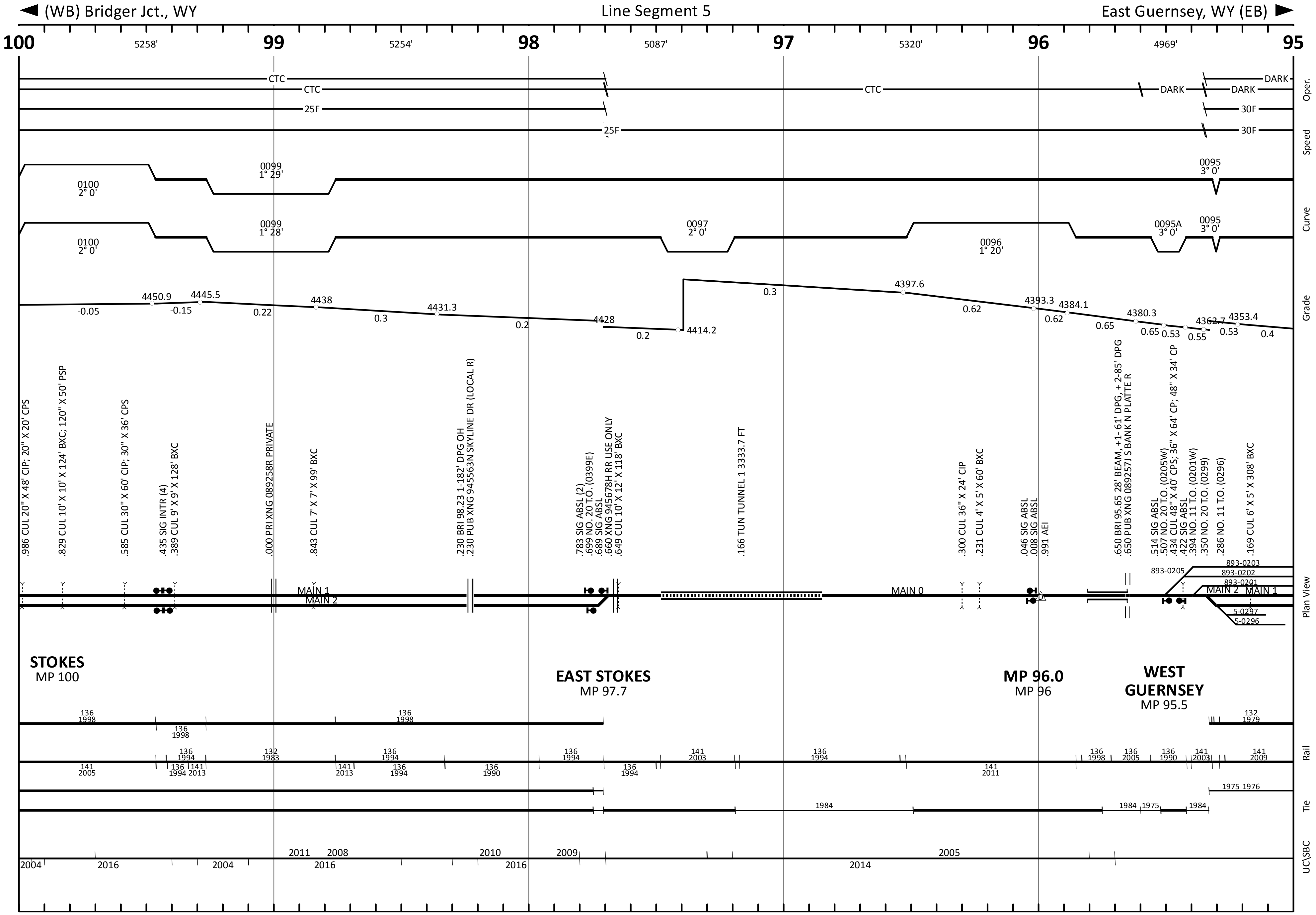
FOREIGN TRACK
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: WENDWY
FSAC: 32137
REVISED: 6/30/2015
TEAM: WENDO4009.DGN
TRK CHT: CAN015.dgn
TEAM PG 009



BNSF RAILWAY

System Maintenance and Planning

Canyon Subdivision

Powder River Operating Division

Powder River West Engineering Division

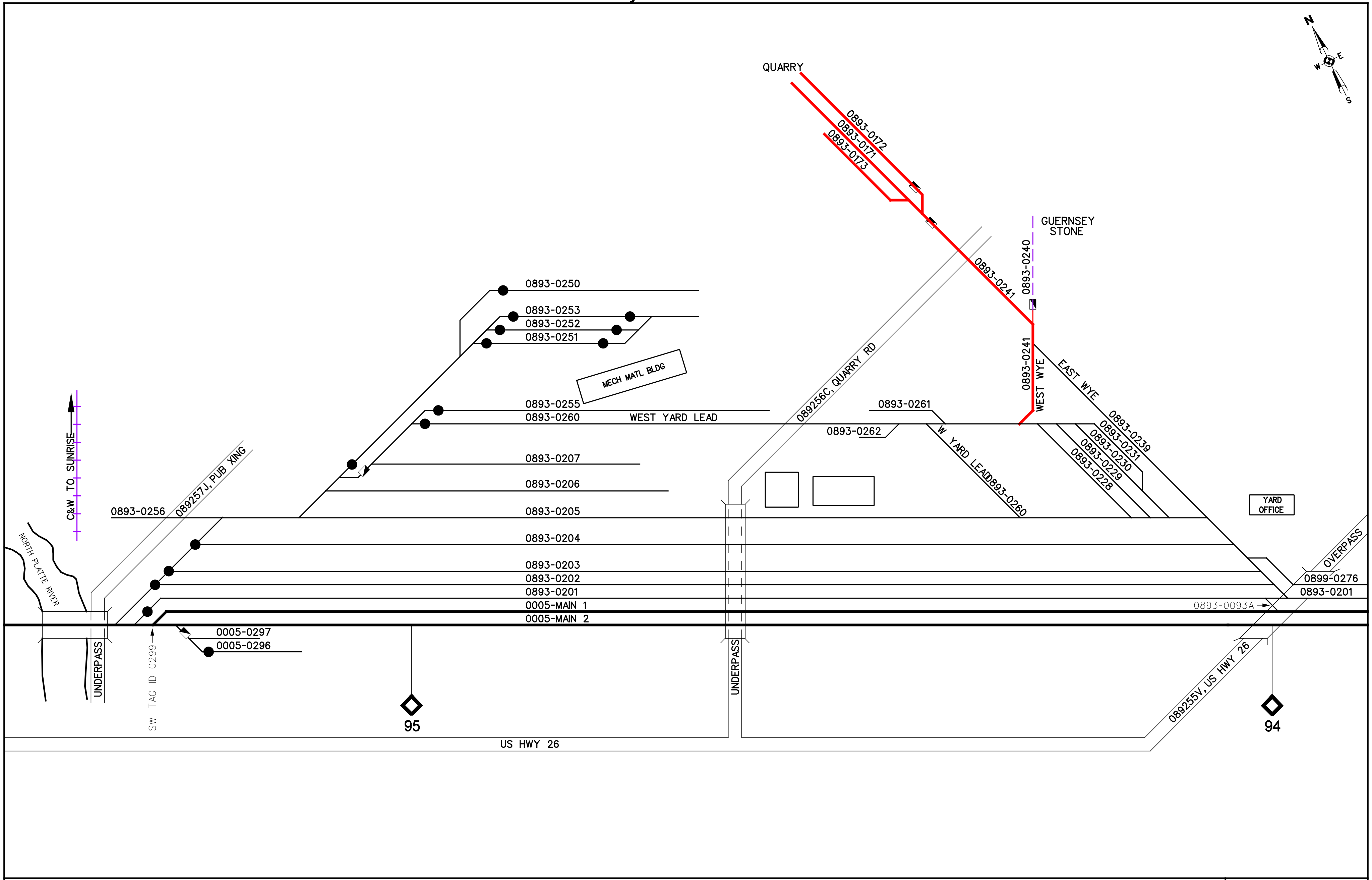
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

GUERNSEY, WY
Canyon Subdivision

← Bridger Jct., WY East Guernsey, WY →



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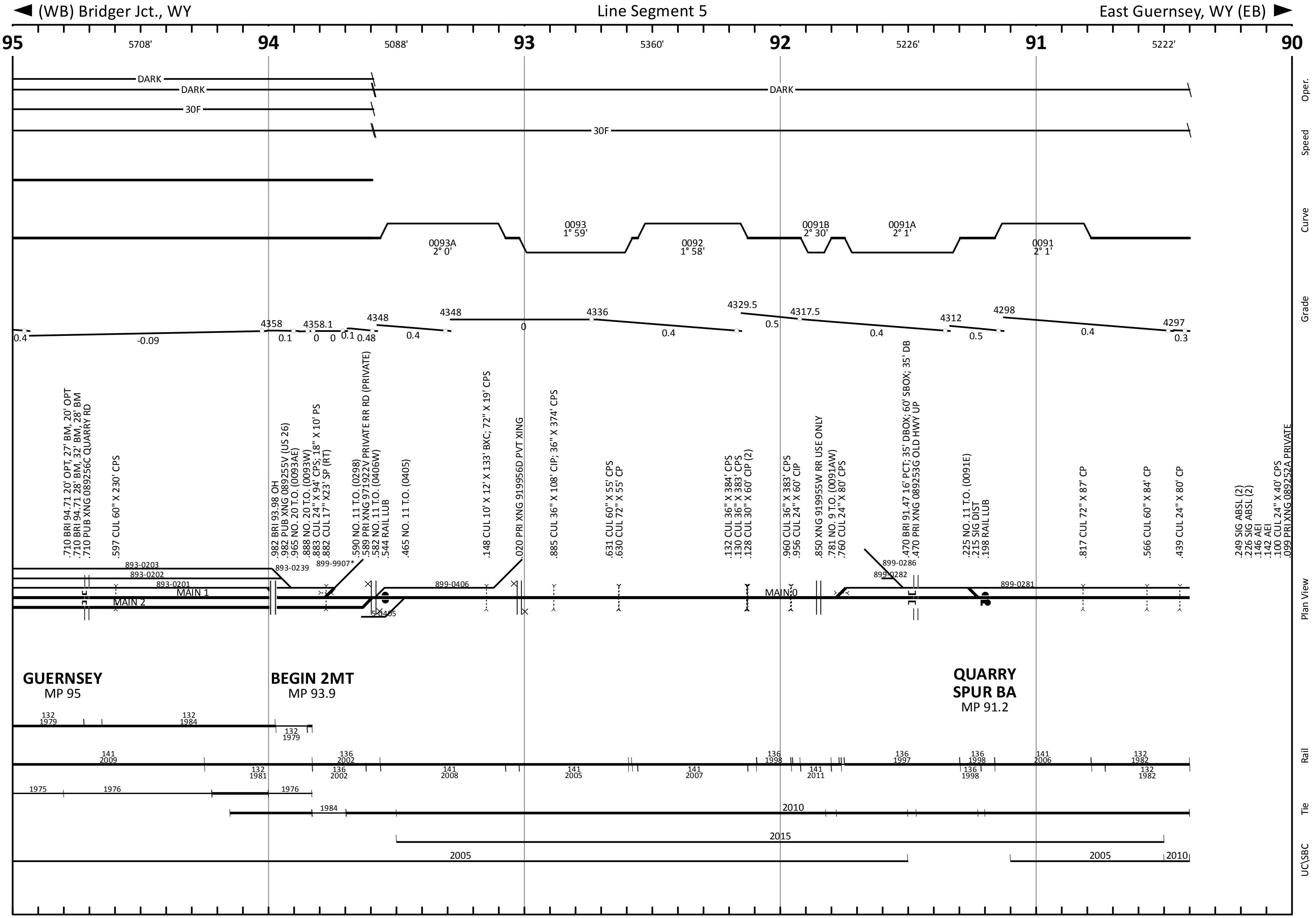
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: GUERWY
FSAC: 32129
REVISED: 1/30/2017
TEAM: GUER01011.DGN
TRK CHT: CAN017.dgn
TEAM PG 011



BNSF RAILWAY

System Maintenance and Planning

Canyon Subdivision

Powder River Operating Division

Powder River West Engineering Division

Engineering Track Chart

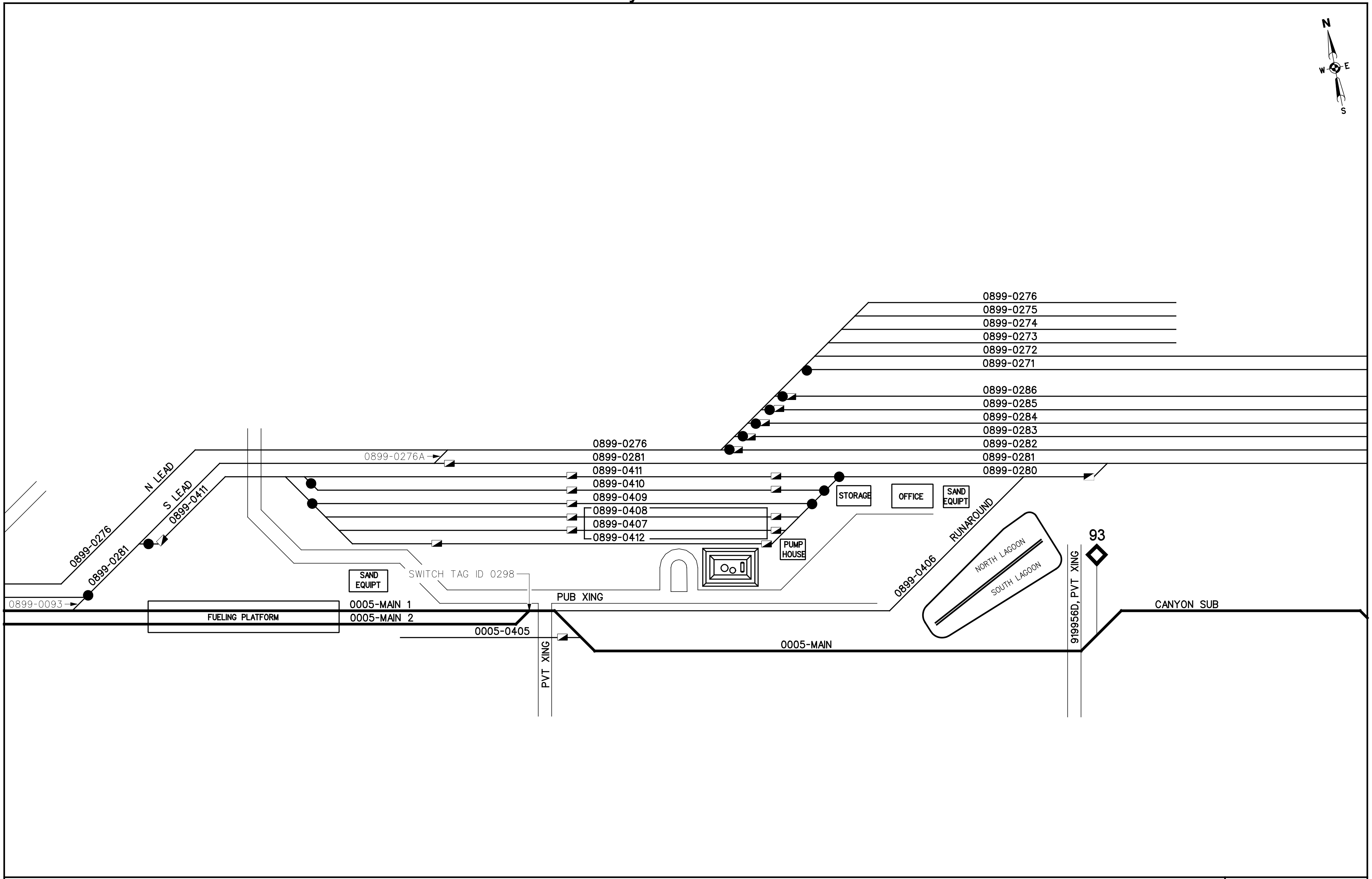
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 11, 2018

GUERNSEY, WY
Canyon Subdivision

◄— Bridger Jct., WY

Northport, NE —►



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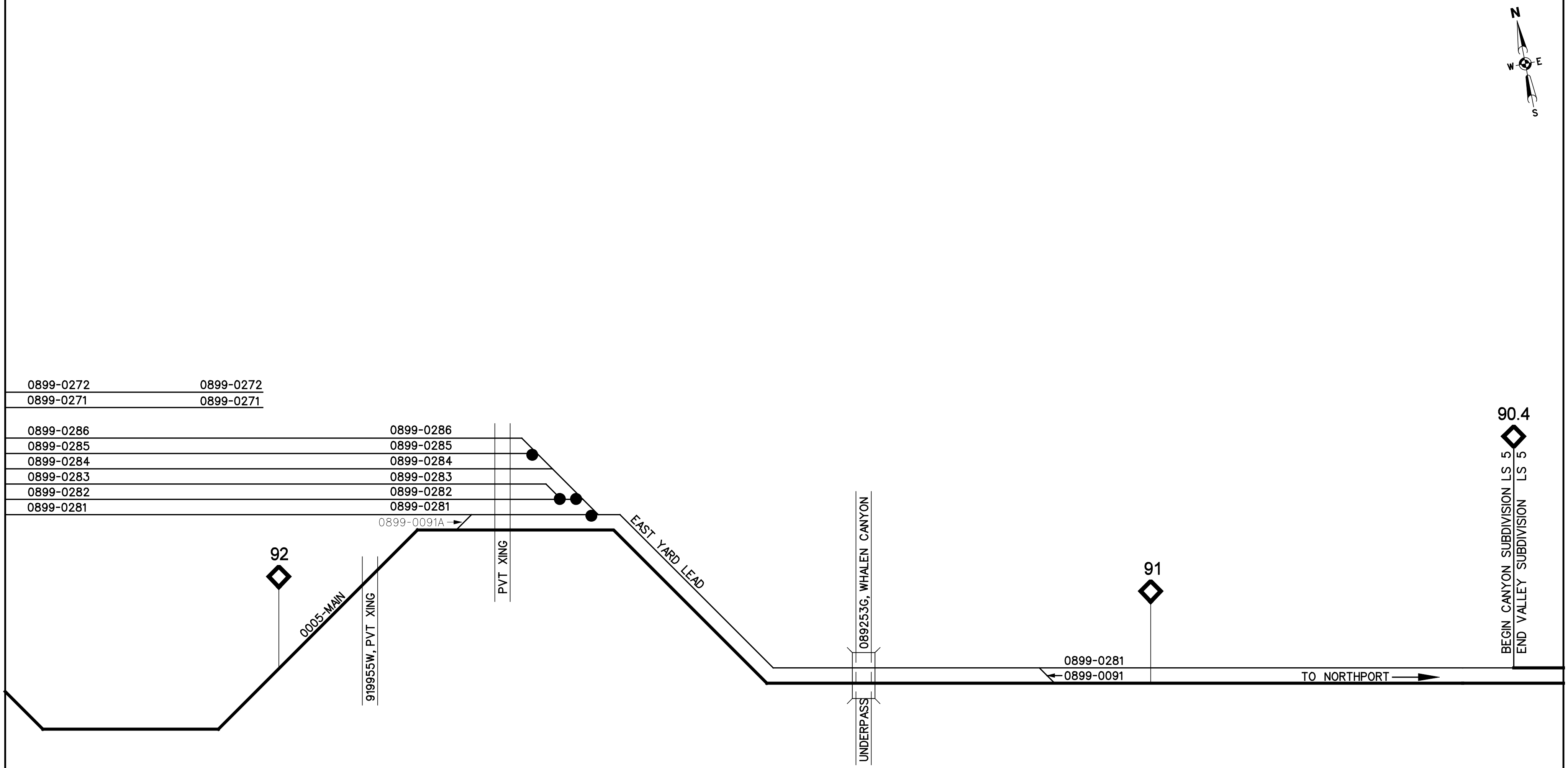
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: GUERWY
FSAC: 32129
REVISED: 6/30/2015
TEAM: GUER02013.DGN
TRK CHT: CAN019.dgn

GUERNSEY, WY
Canyon Subdivision

← Bridger Jct., WY

Northport, NE →



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TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: GUERWY
FSAC: 32129
REVISED: 6/30/2015
TEAM: GUER02015.DGN
TRK CHT: CAN020.dgn
TEAM PG 015

Track Chart
Ravenna Subdivision

Lincoln, NE to West Ravenna, NE

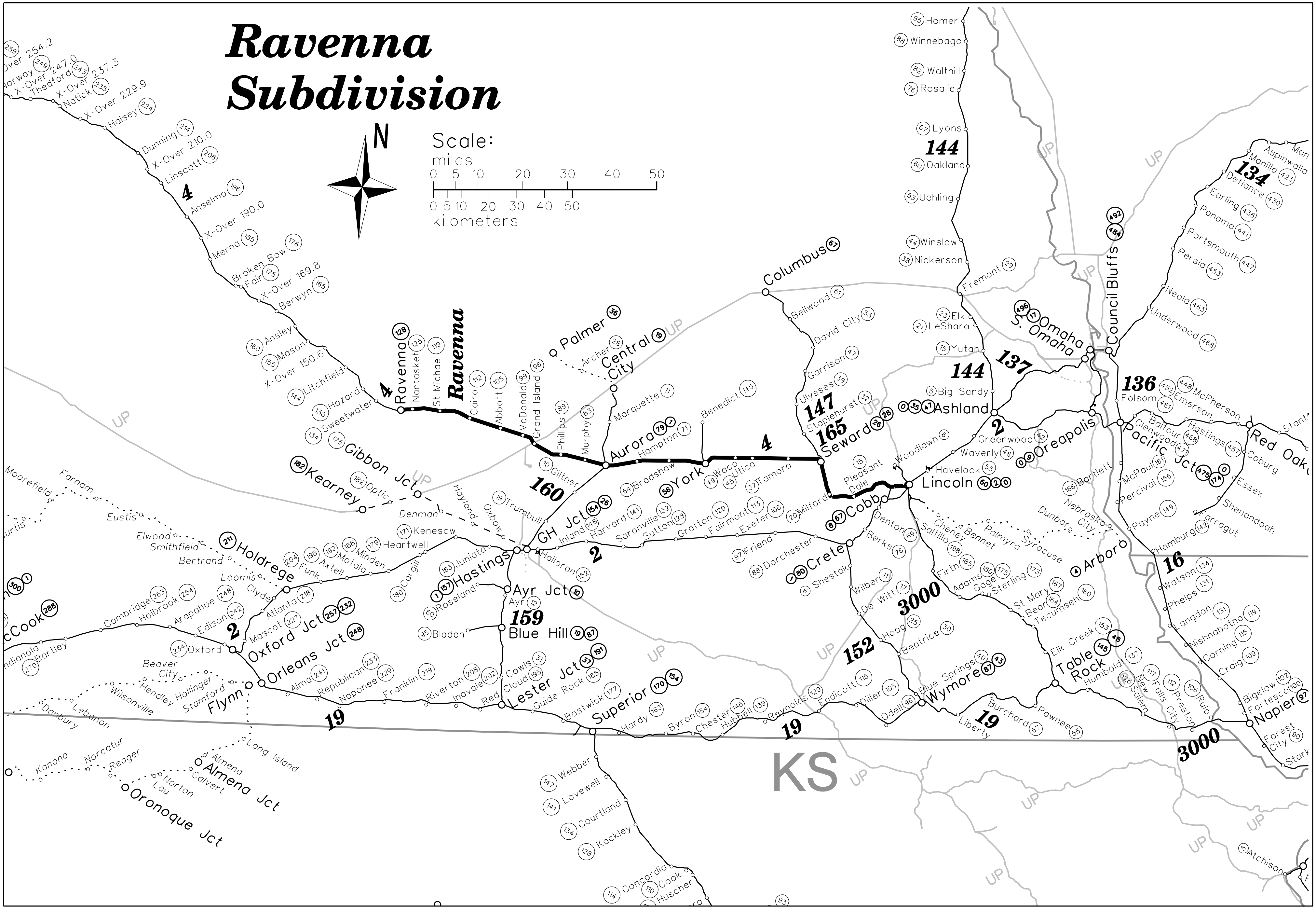
MP 11.082 to MP 128.2

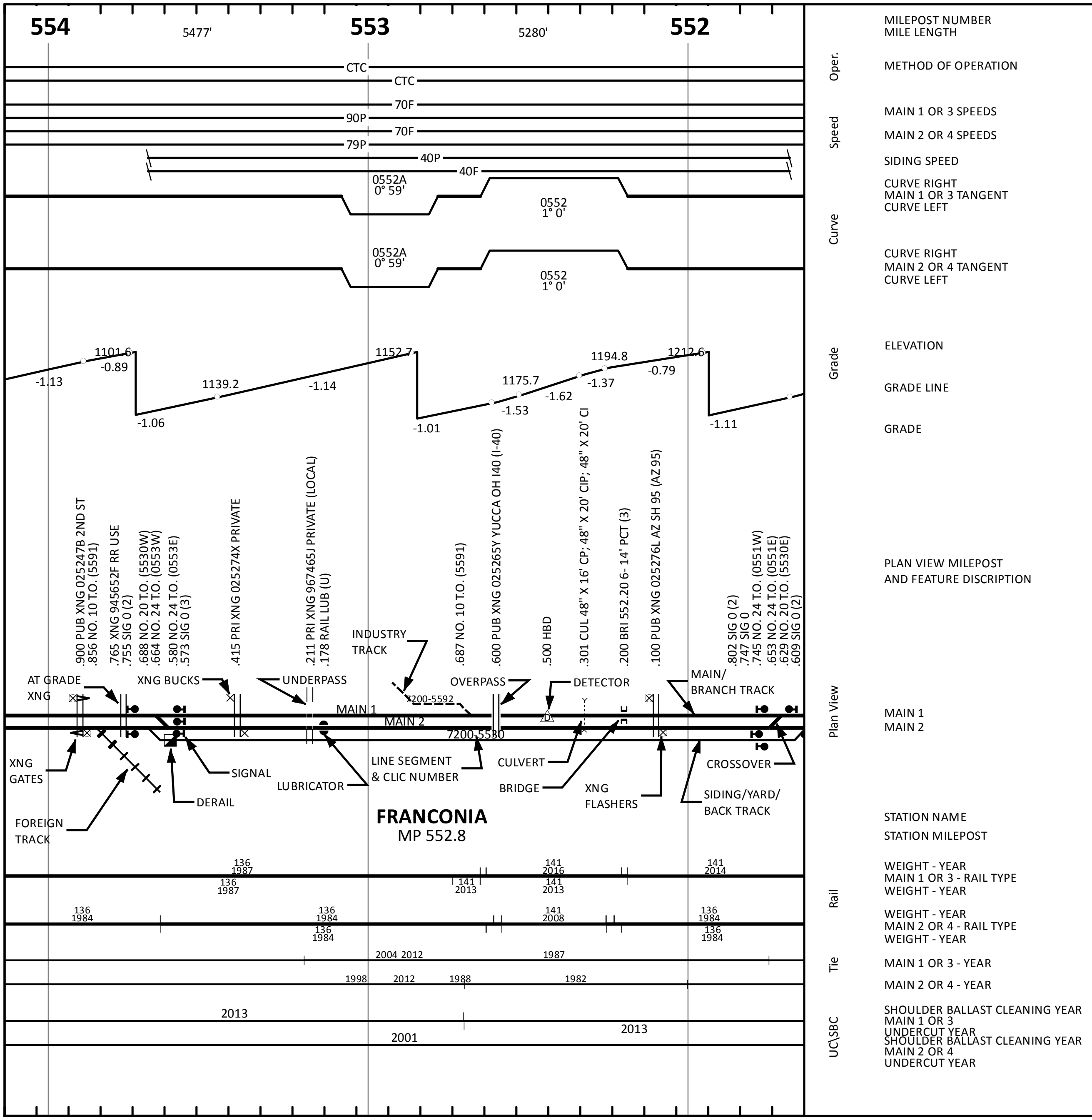
See each page for latest revised date.

Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Ravenna Subdivision





TRACK CHART FEATURE LEGEND

NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280') VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

FILE: Y:\drawings\trkchrts\ASTC\MXD_Files\TC_Legend.mxd

Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

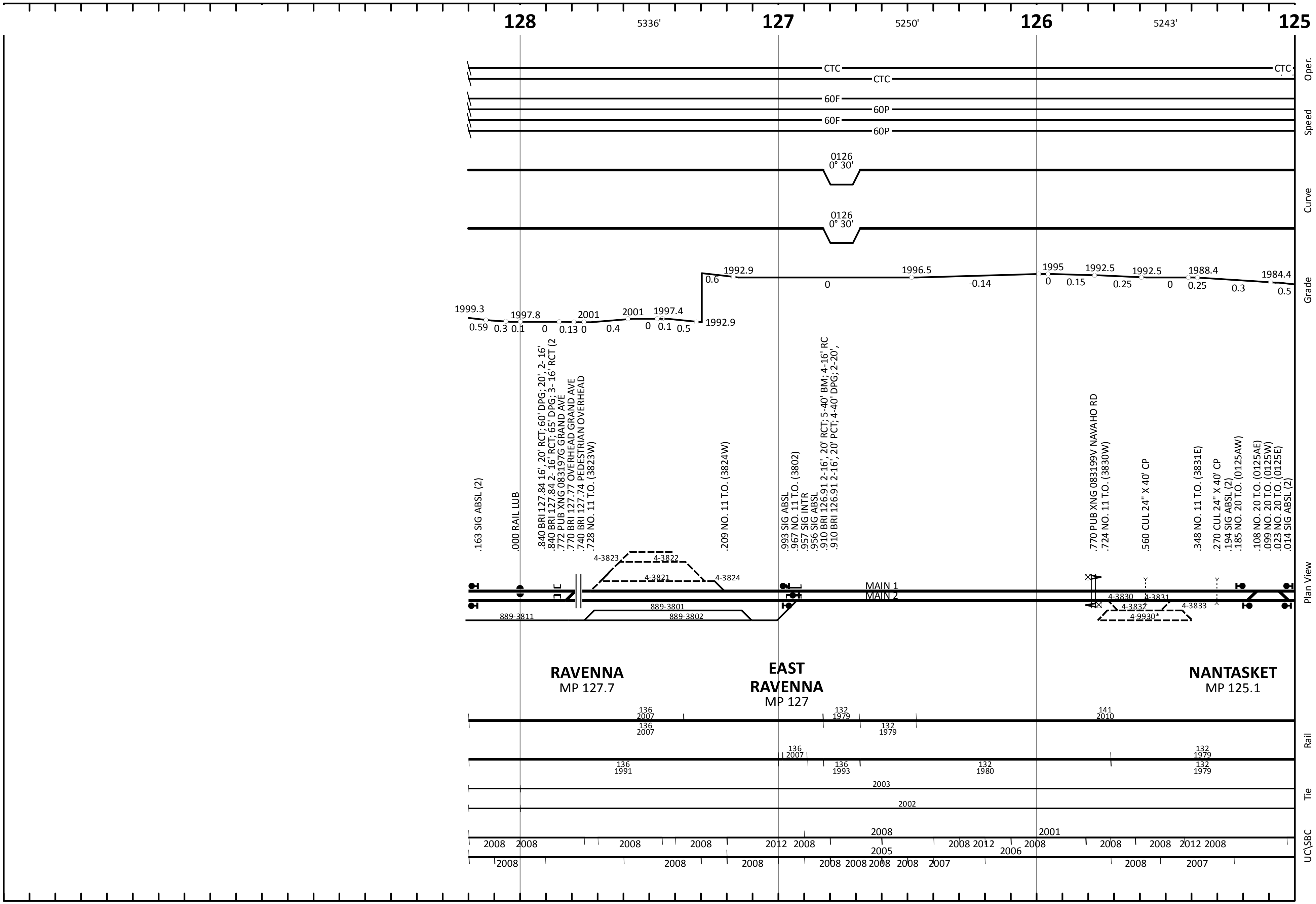
Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL

◄ (WB) Ravenna, NE Line Segment 4 Lincoln, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

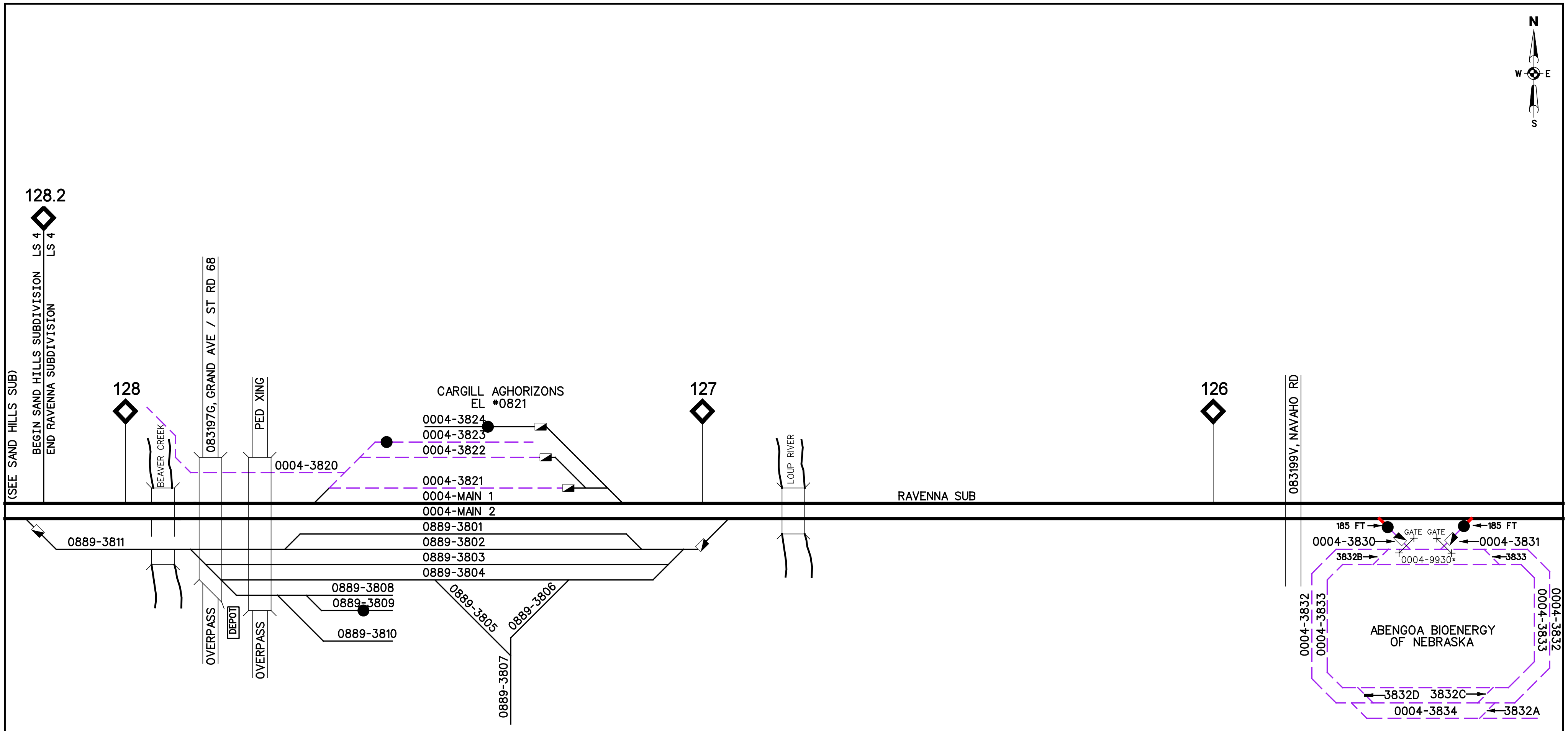
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

RAVENNA, NE
Ravenna Subdivision

← Ravenna, NE   Lincoln, NE →



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─◆─	INDUSTRY OWNED & BNSF MAINT	───	TRACKAGE RIGHTS
– – –	IND OWNED & MAINT	┼┼┼	FOREIGN TRACK
●─●─●	INDUSTRY MAINT & BNSF OWNED (LEASE)		
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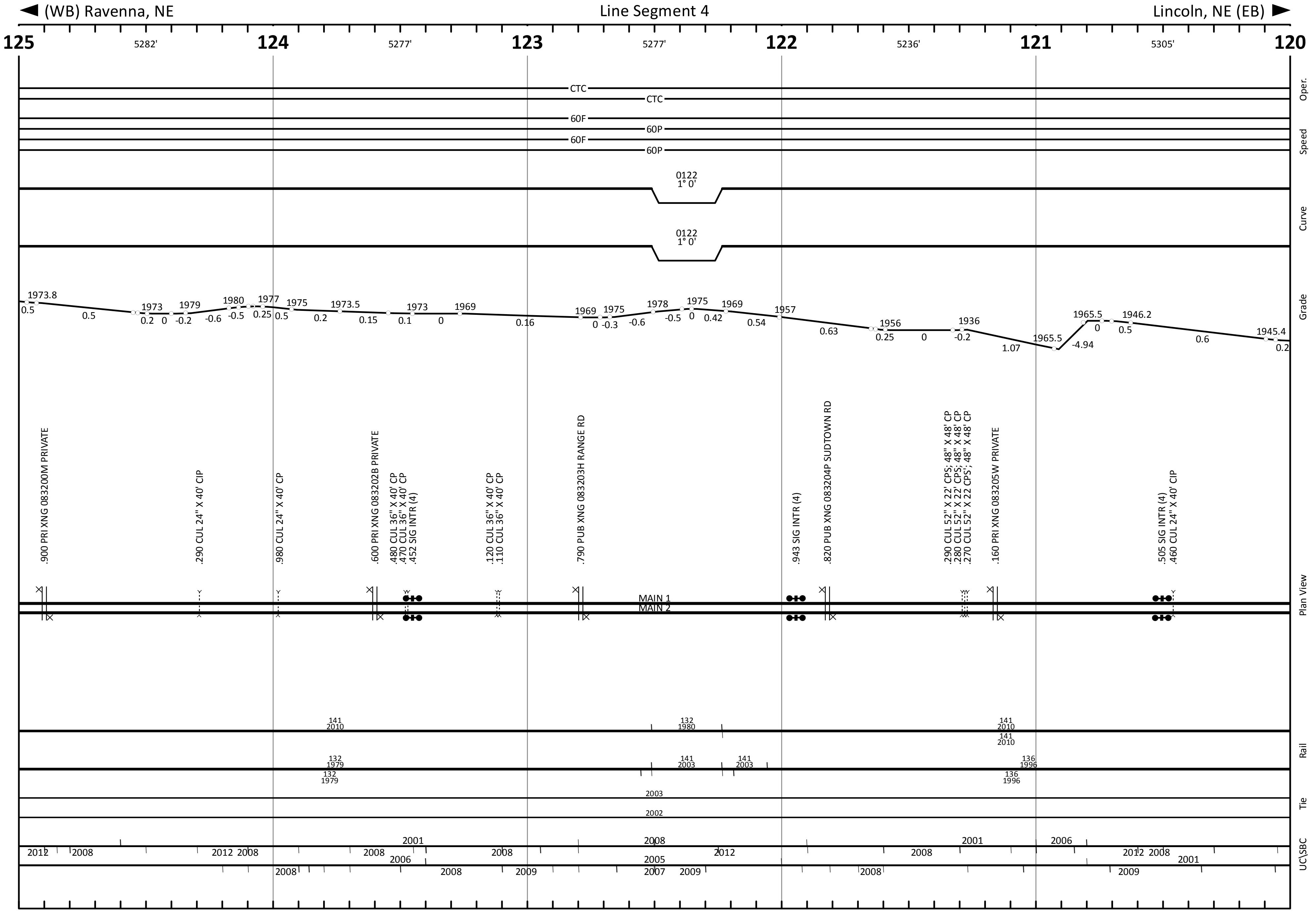
◪	DERAIL		

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: REVENN
FSAC: 30126
REVISED: 1/23/2017
TEAM: REAVE38003.DGN
TRK CHT: RAV006.DGN
TEAM PG 003



BNSF RAILWAY

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Powder River Operating Division

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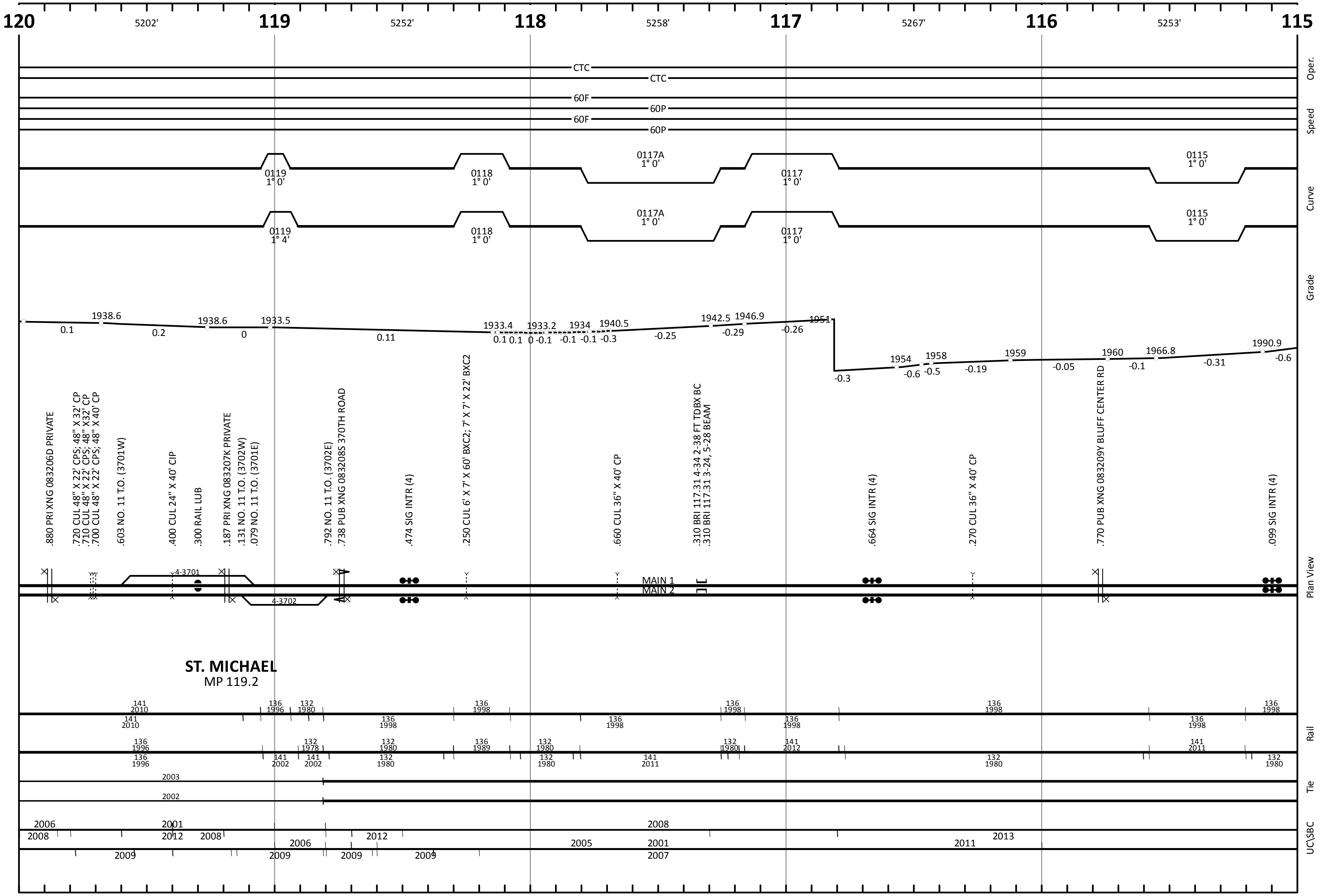
Revised to June 22, 2018

◄ (WB) Ravenna, NE | Line Segment 4 | Lincoln, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

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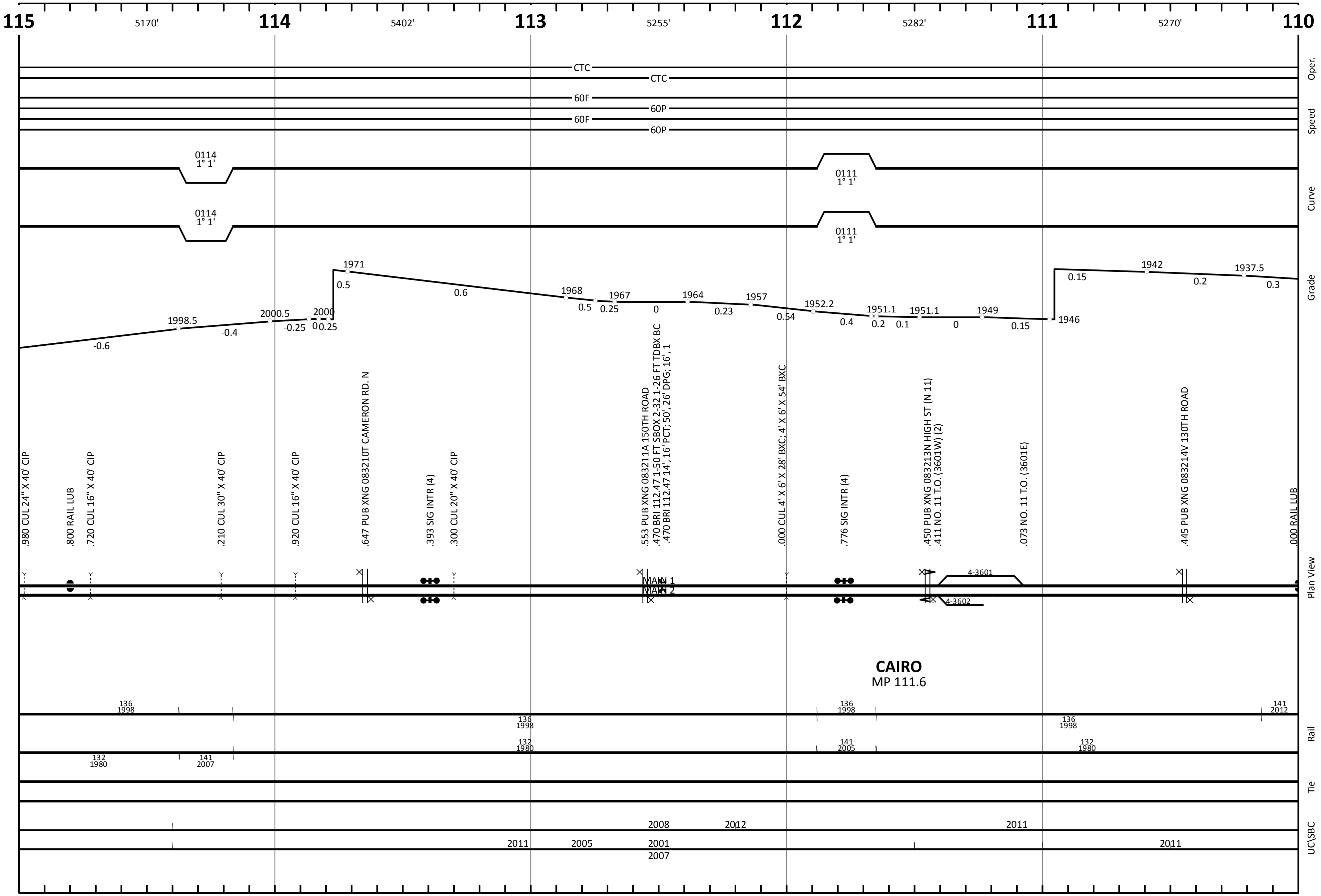
Revised to June 22, 2018 Page 8 of 44

◄ (WB) Ravenna, NE Line Segment 4 Lincoln, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

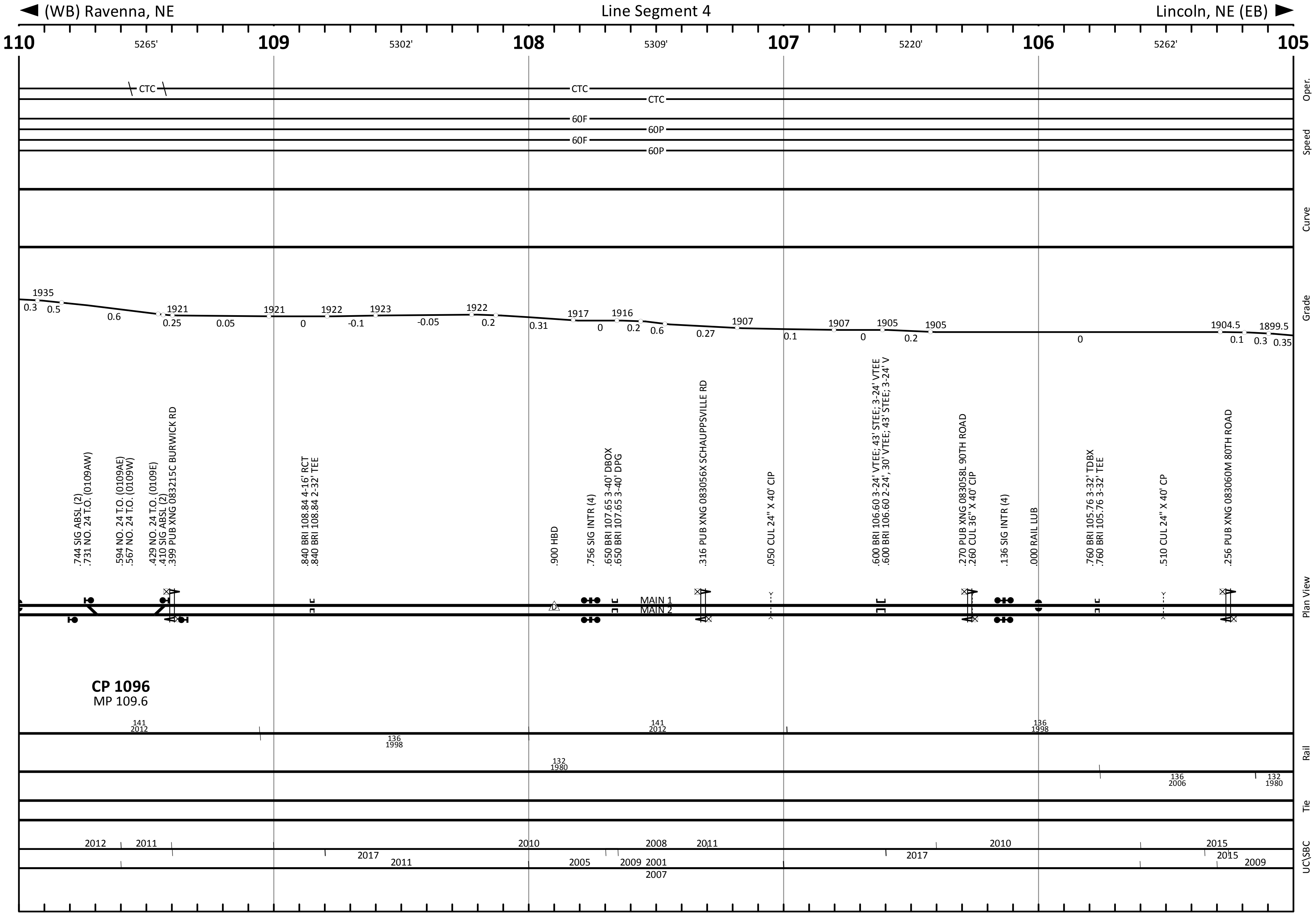
Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018



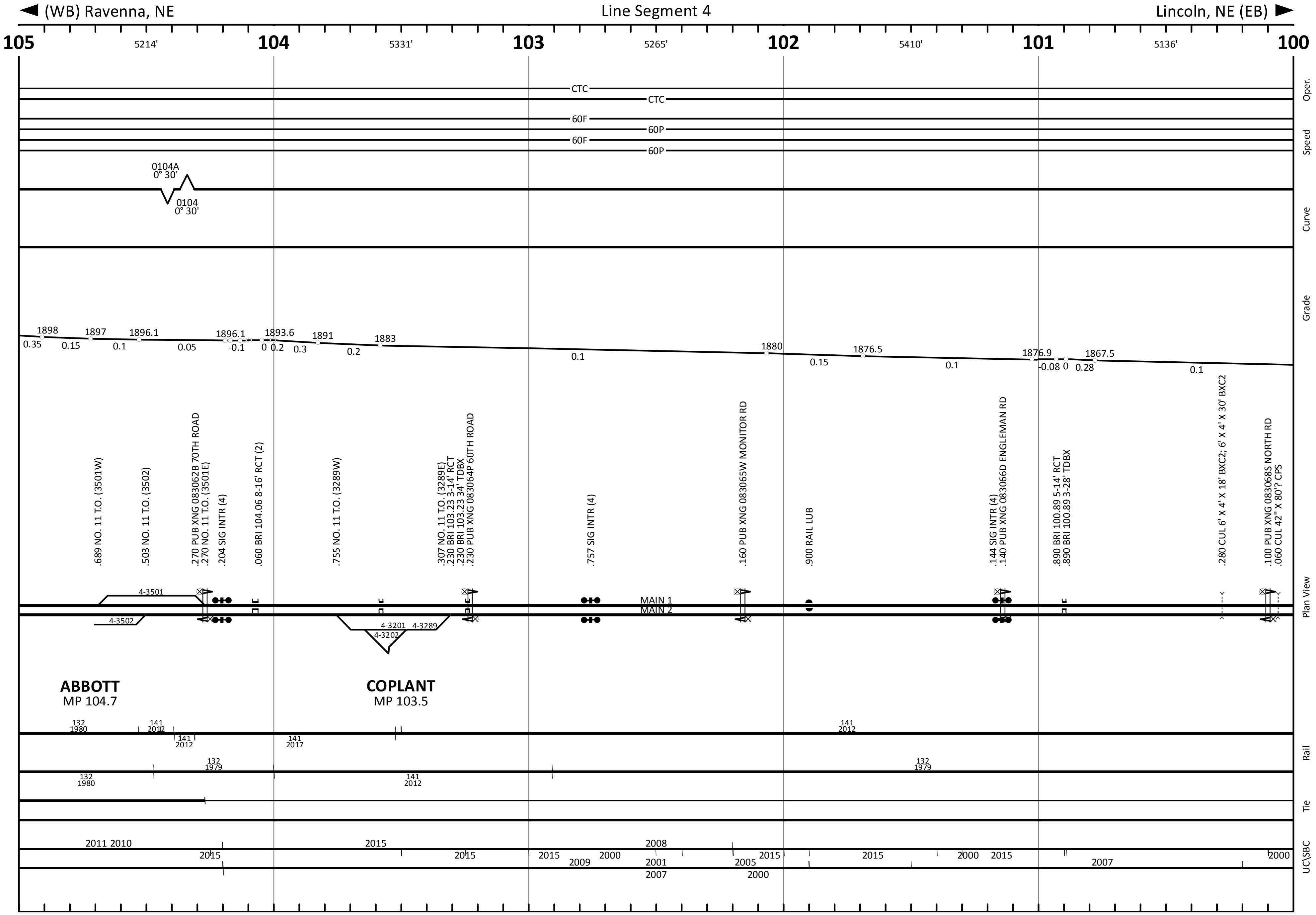
System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

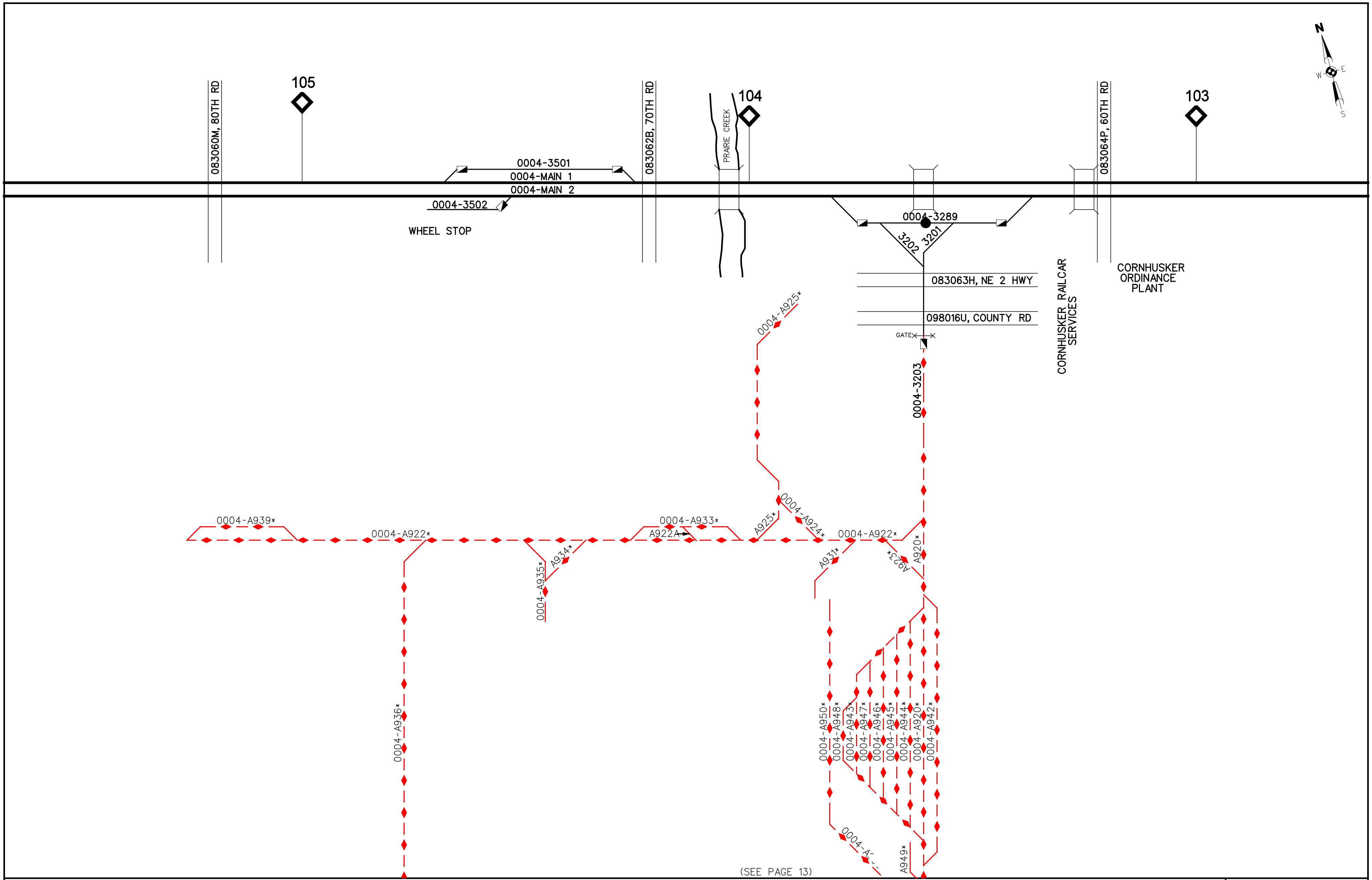
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

ABBOTT, NE

Ravenna Subdivision

← Ravenna, NE Hobson, NE →



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
SPECIAL CONDITIONS (ITEM #7)
FOR ADDITIONAL QUESTIONS ON PHYSICAL CHARACTERISTICS, CONTACT A LOCAL DIVISION MANAGER
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

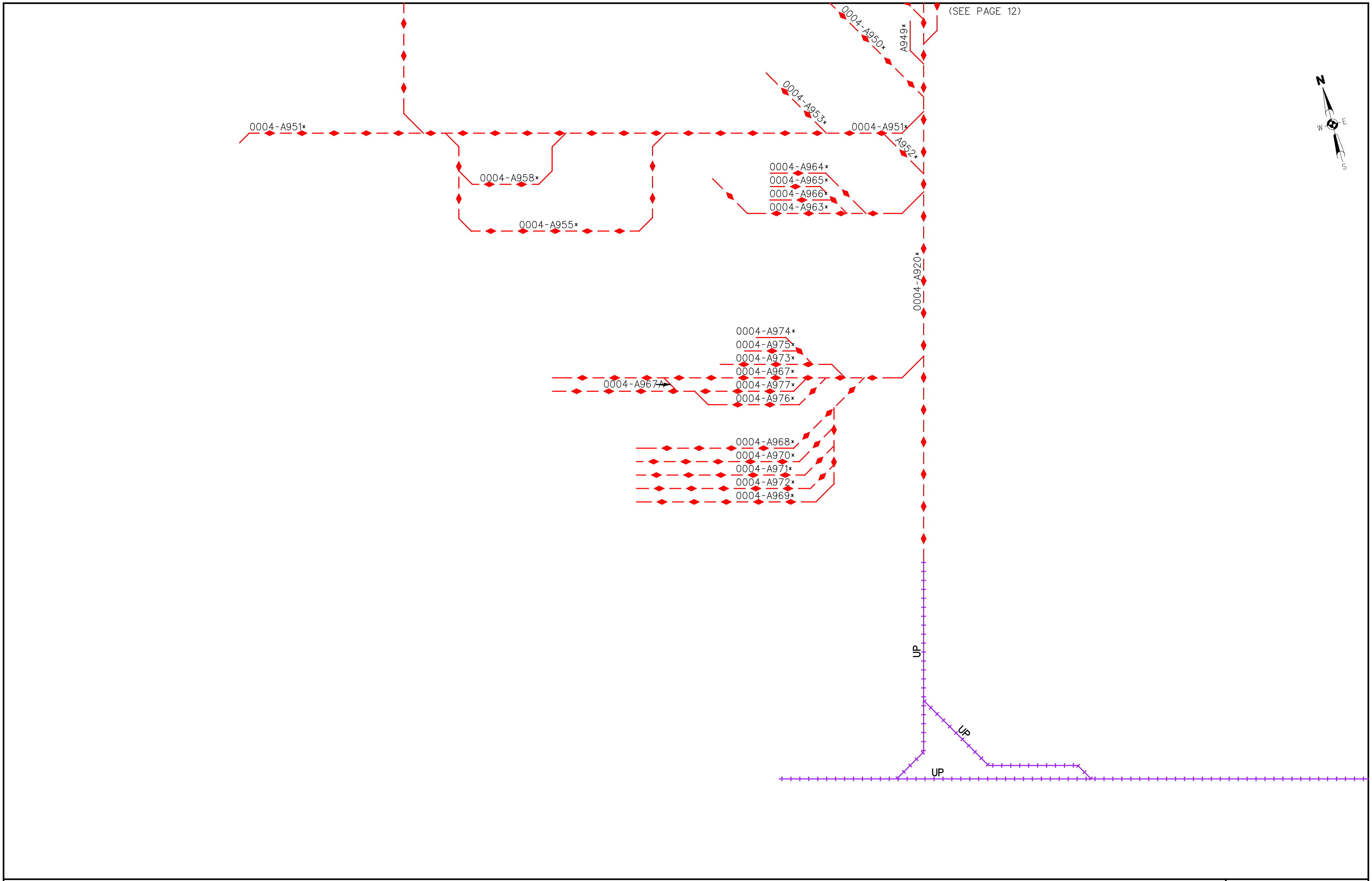
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ABBOTT
FSAC: 30104
REVISED: 11/7/2014
TEAM: ABBO32009.DGN
TRK CHT: RAV012.DGN
TEAM PG 009

ABBOTT, NE

Ravenna Subdivision



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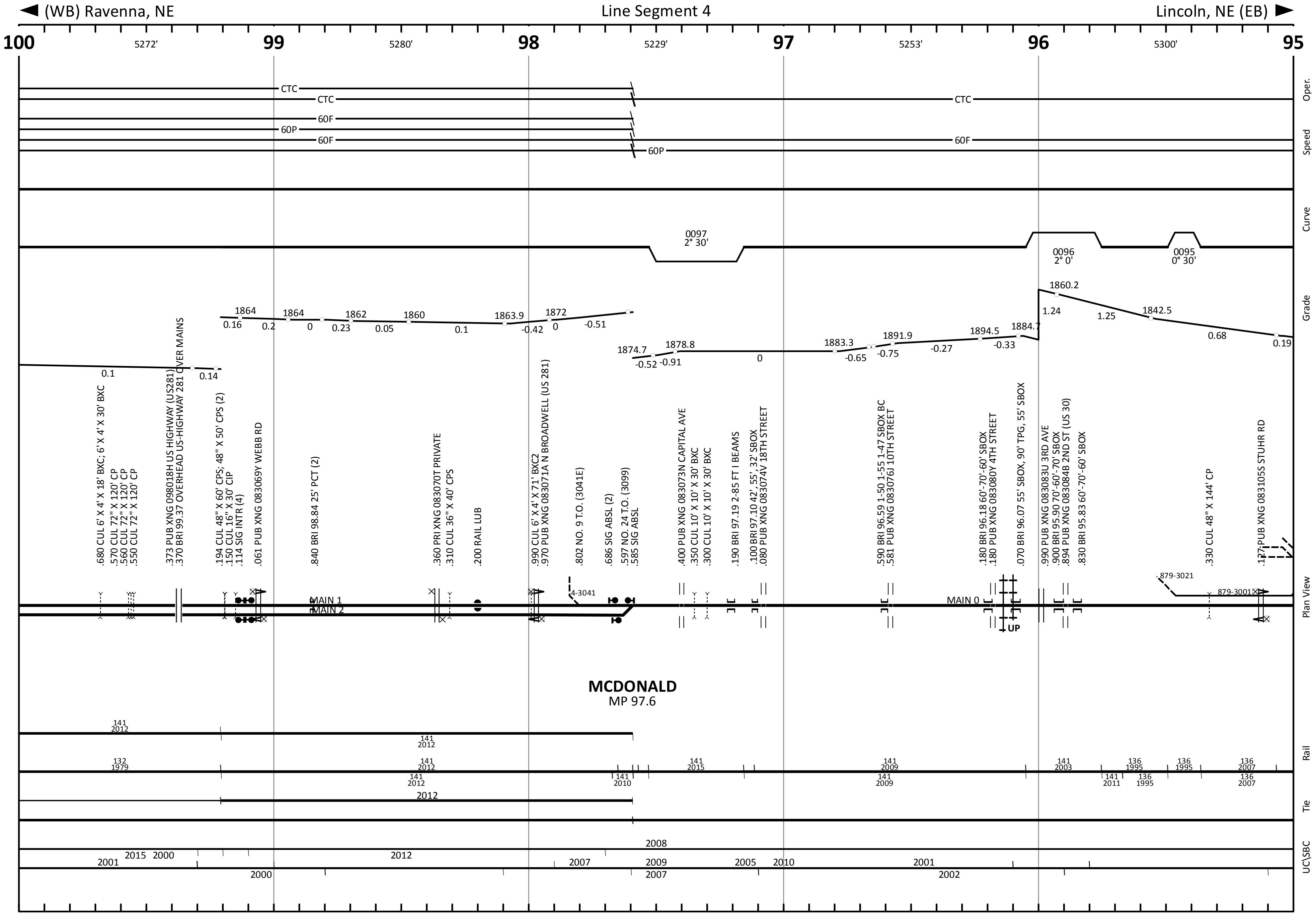
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: ABBOTT
FSAC: 30104
REVISED: 11/7/2014
TEAM: ABB099011.DGN
TRK CHT: RAV013.DGN



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

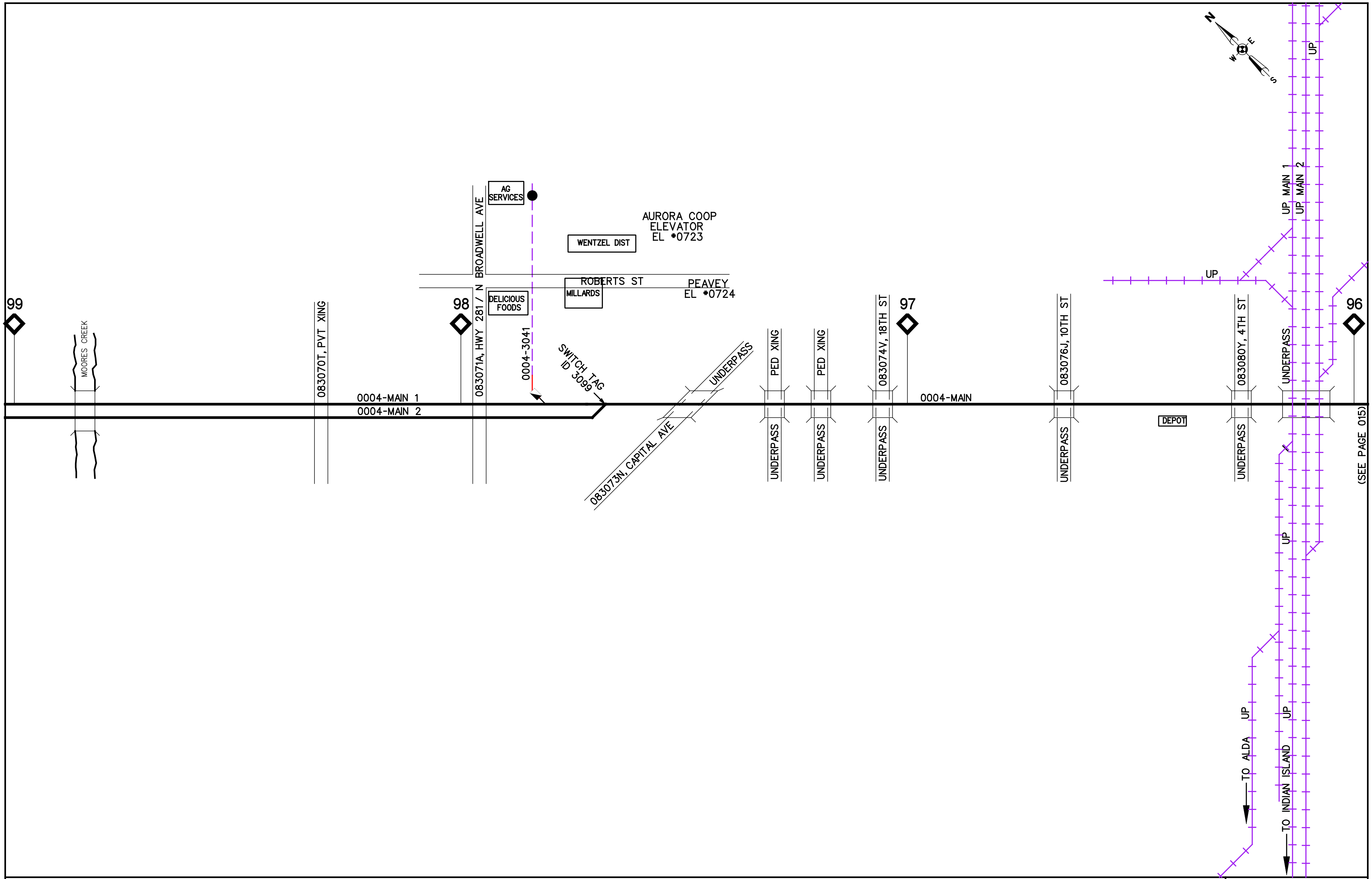
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018 Page 14 of 44

GRAND ISLAND, NE
Ravenna Subdivision

◄— Ravenna, NE

Lincoln, NE —►



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———	BNSF OWNED & MAINT
—◆—◆—	INDUSTRY OWNED & BNSF MAINT
- - - -	IND OWNED & MAINT
—●—●—●—	INDUSTRY MAINT & BNSF OWNED (LEASE)
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪	DERAIL
—┼—┼—	JOINT FACILITIES
———	TRACKAGE RIGHTS
┼┼—┼—┼	FOREIGN TRACK

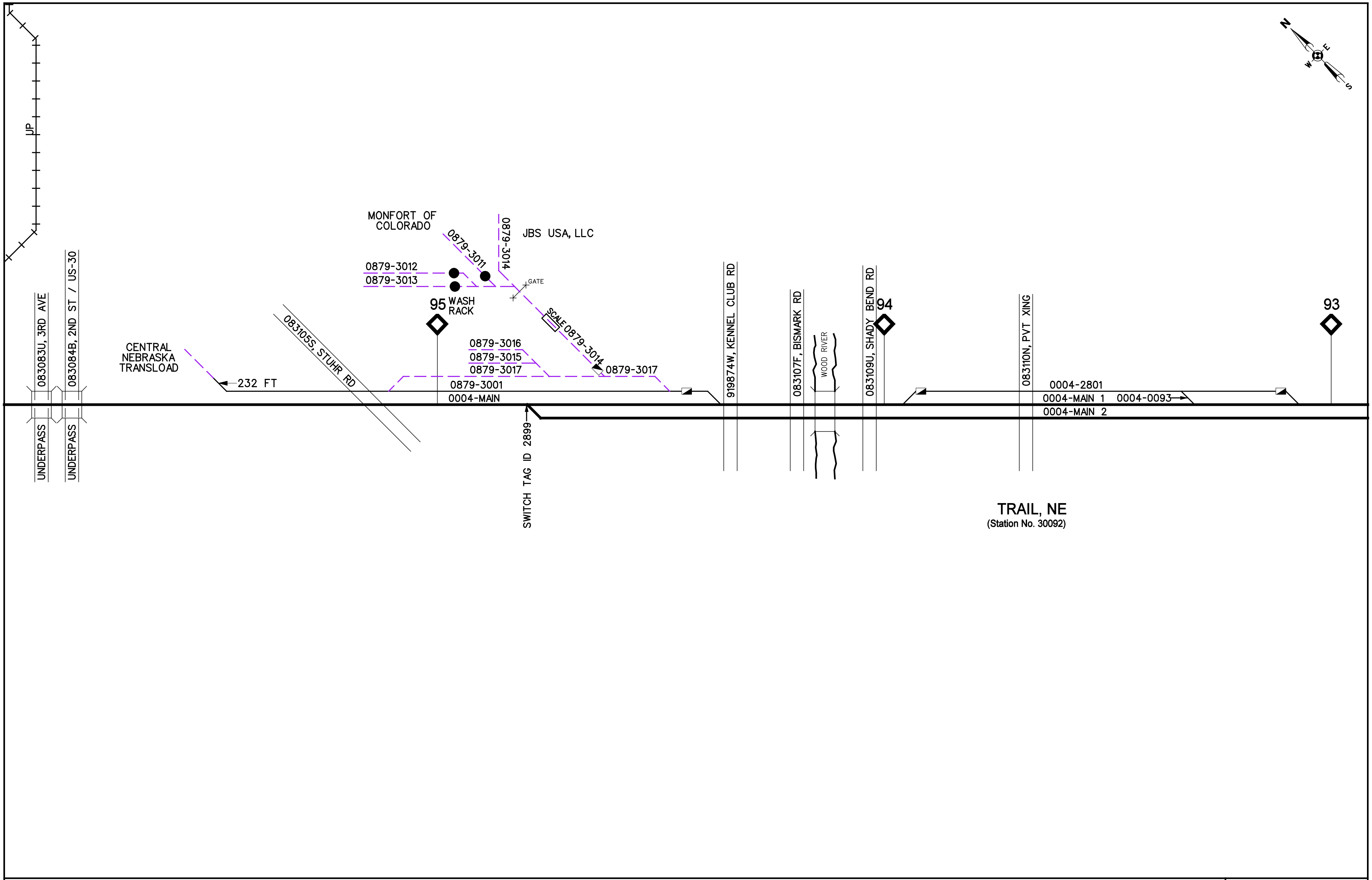
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: GRAISL
FSAC: 30092
REVISED: 1/27/2016
TEAM: GRAN30013.DGN
TRK CHT: RAV015.DGN

GRAND ISLAND, NE
Ravenna Subdivision

◄— Ravenna, NE

Lincoln, NE —►



BNSF RAILWAY

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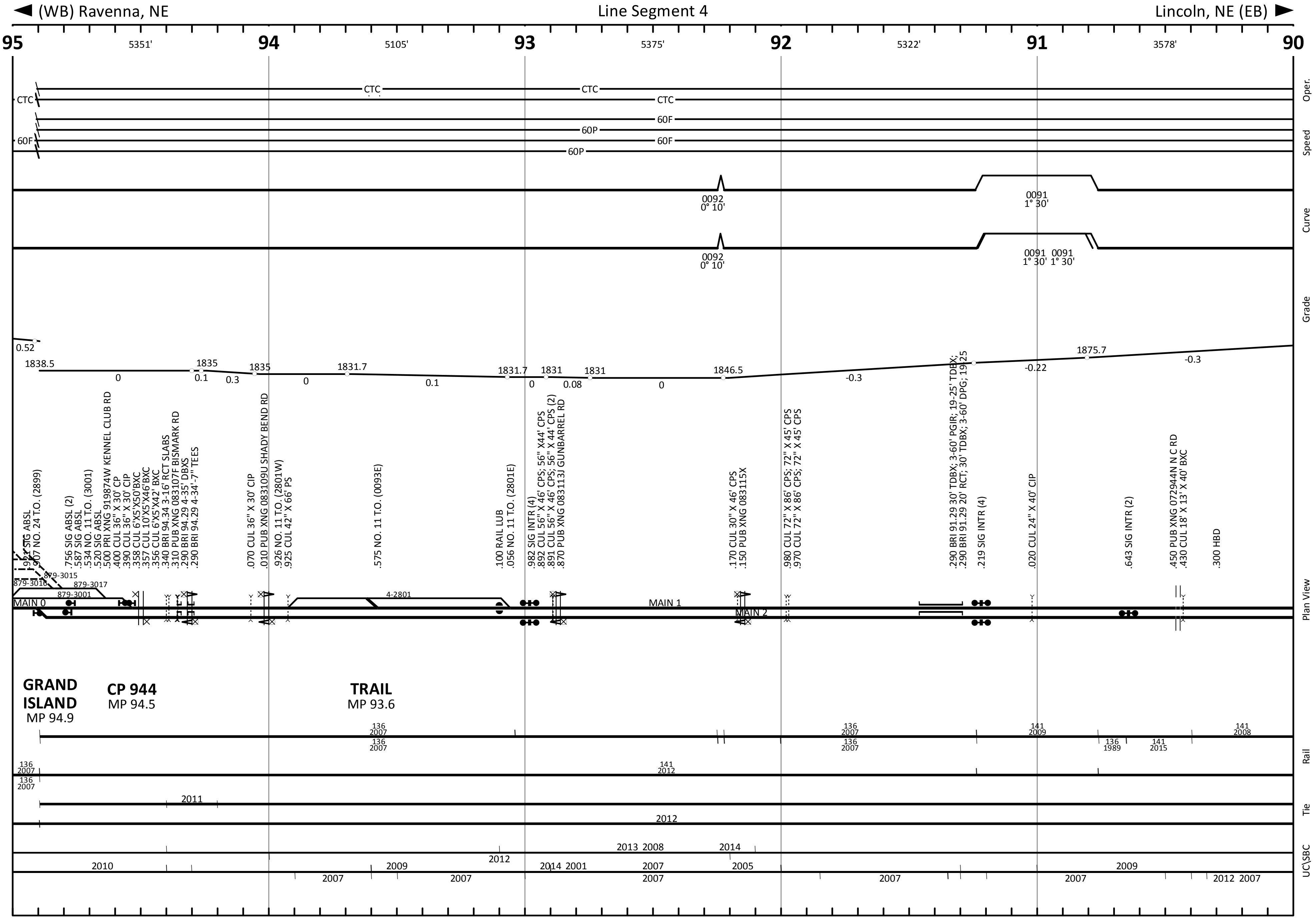
◩	DERAIL
—┼—┼—	JOINT FACILITIES
▬▬▬	TRACKAGE RIGHTS
—┼—┼—┼—	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: GRAISL
FSAC: 30092
REVISED: 8/2/2017
TEAM: GRAN28015.DGN
TRK CHT: RAV016.DGN



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

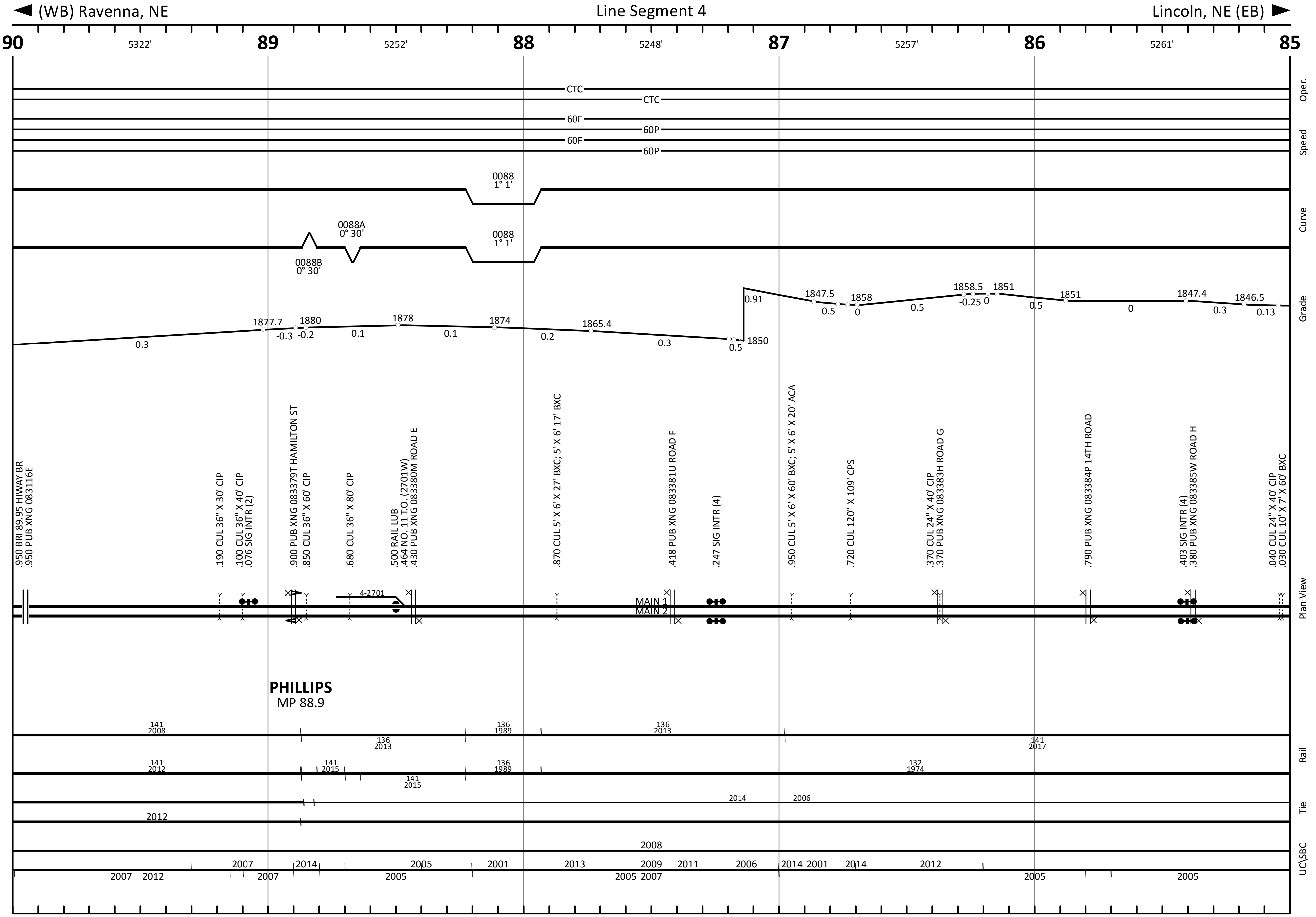
Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018



System Maintenance and Planning

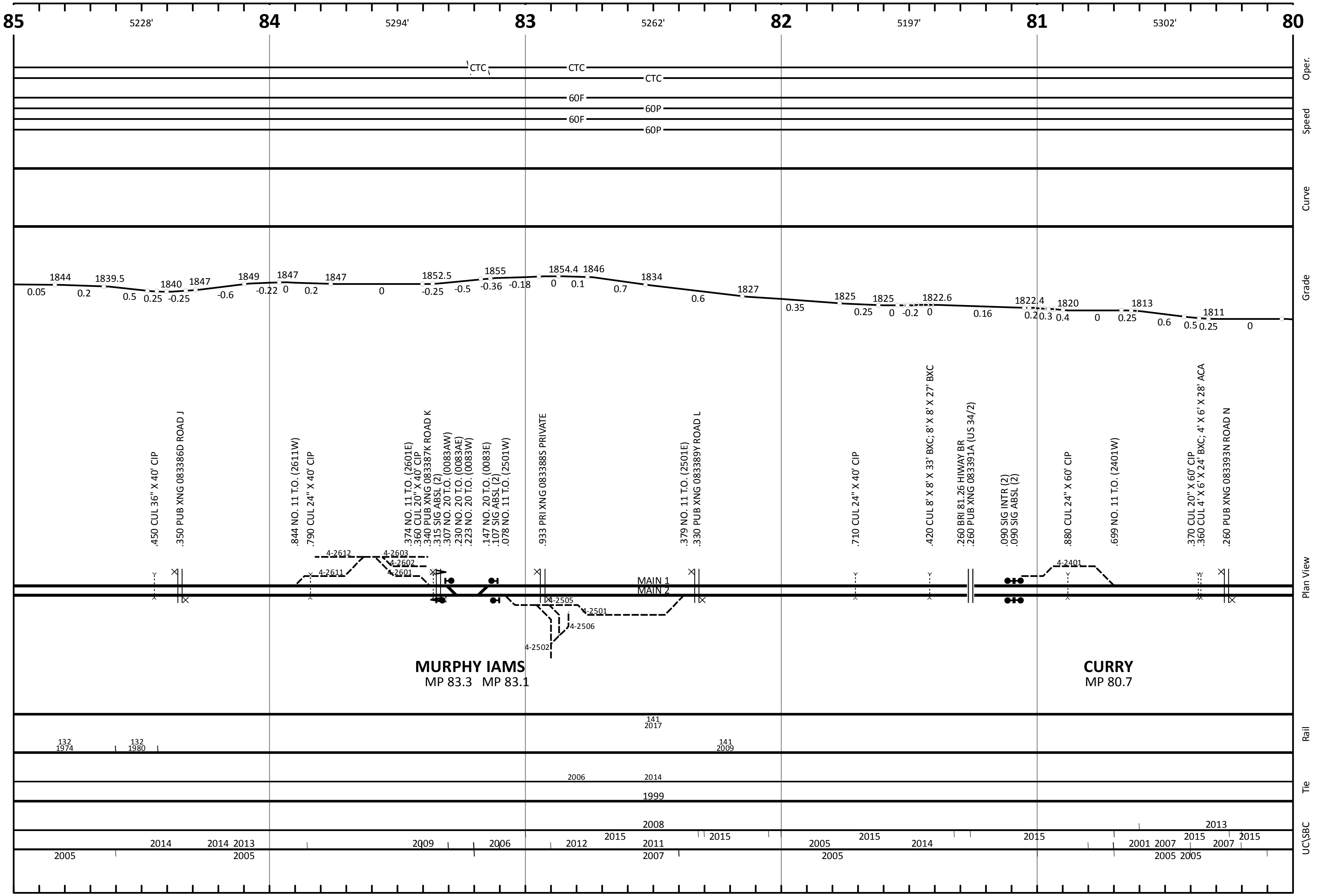
Ravenna Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 22, 2018

◄ (WB) Ravenna, NE Line Segment 4 Lincoln, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

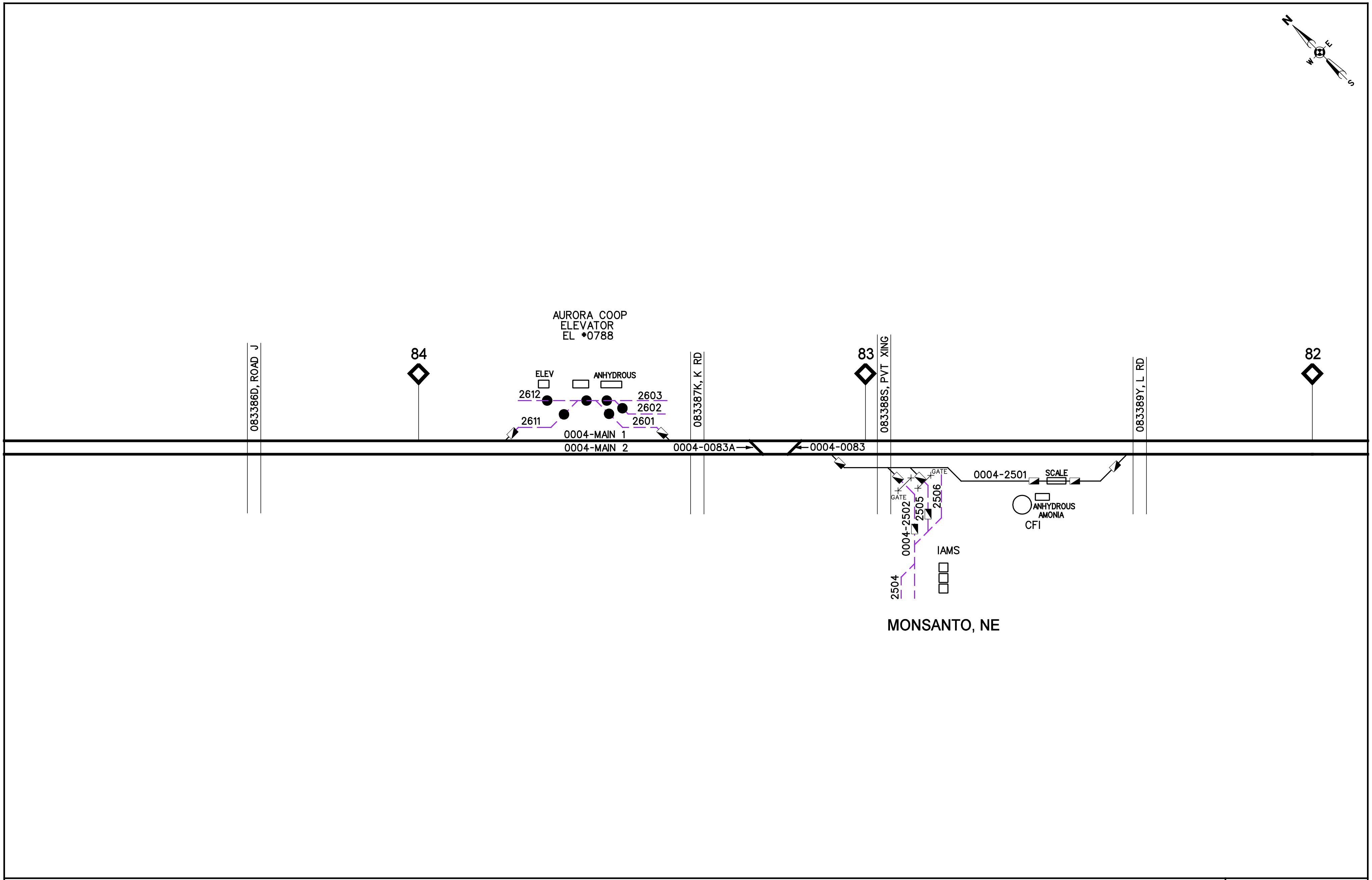
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

MURPHY, NE
Ravenna Subdivision

← Ravenna, NE

Hobson, NE →



BNSF RAILWAY

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IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
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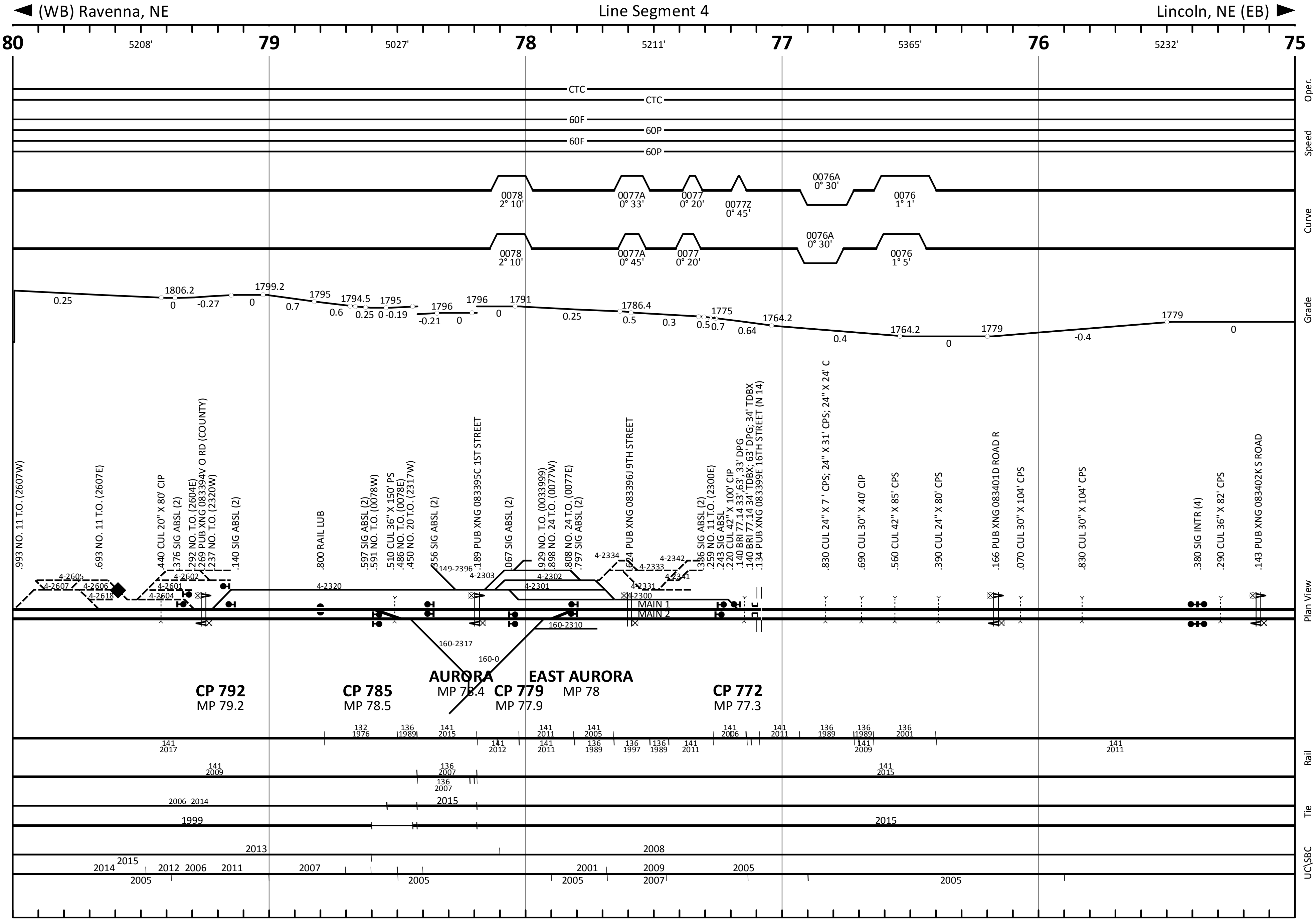
◪ DERAIL
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: MURPHY
FSAC: 30082
REVISED: 11/7/2014
TEAM: MURP25019.DGN
TRK CHT: RAV020.DGN
TEAM PG 019



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

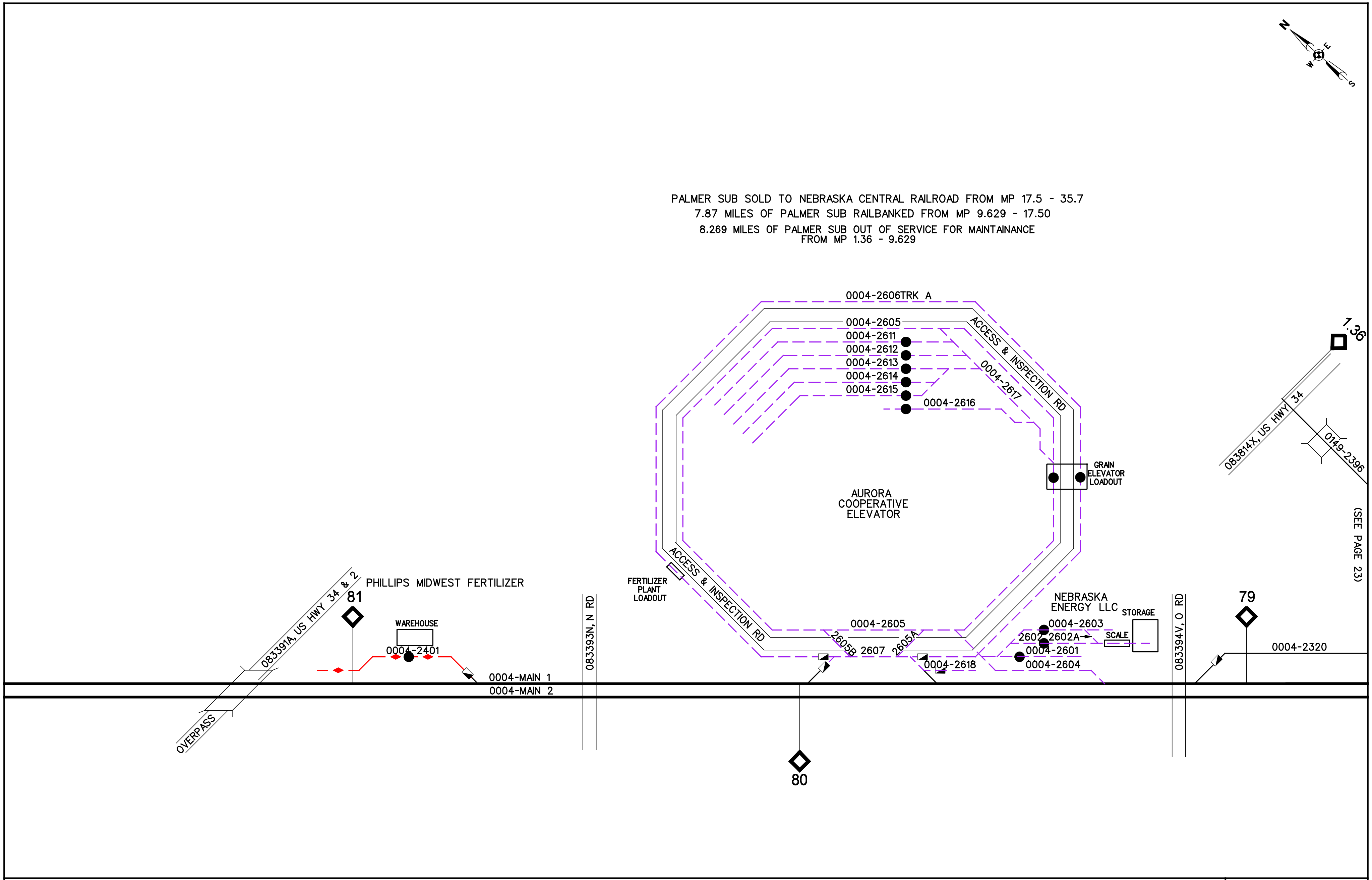
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018 Page 21 of 44

CURRY, NE
Ravenna Subdivision

← Ravenna, NE Hobson, NE →



PALMER SUB SOLD TO NEBRASKA CENTRAL RAILROAD FROM MP 17.5 - 35.7
7.87 MILES OF PALMER SUB RAILBANKED FROM MP 9.629 - 17.50
8.269 MILES OF PALMER SUB OUT OF SERVICE FOR MAINTAINANCE FROM MP 1.36 - 9.629

BNSF RAILWAY

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BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
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DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

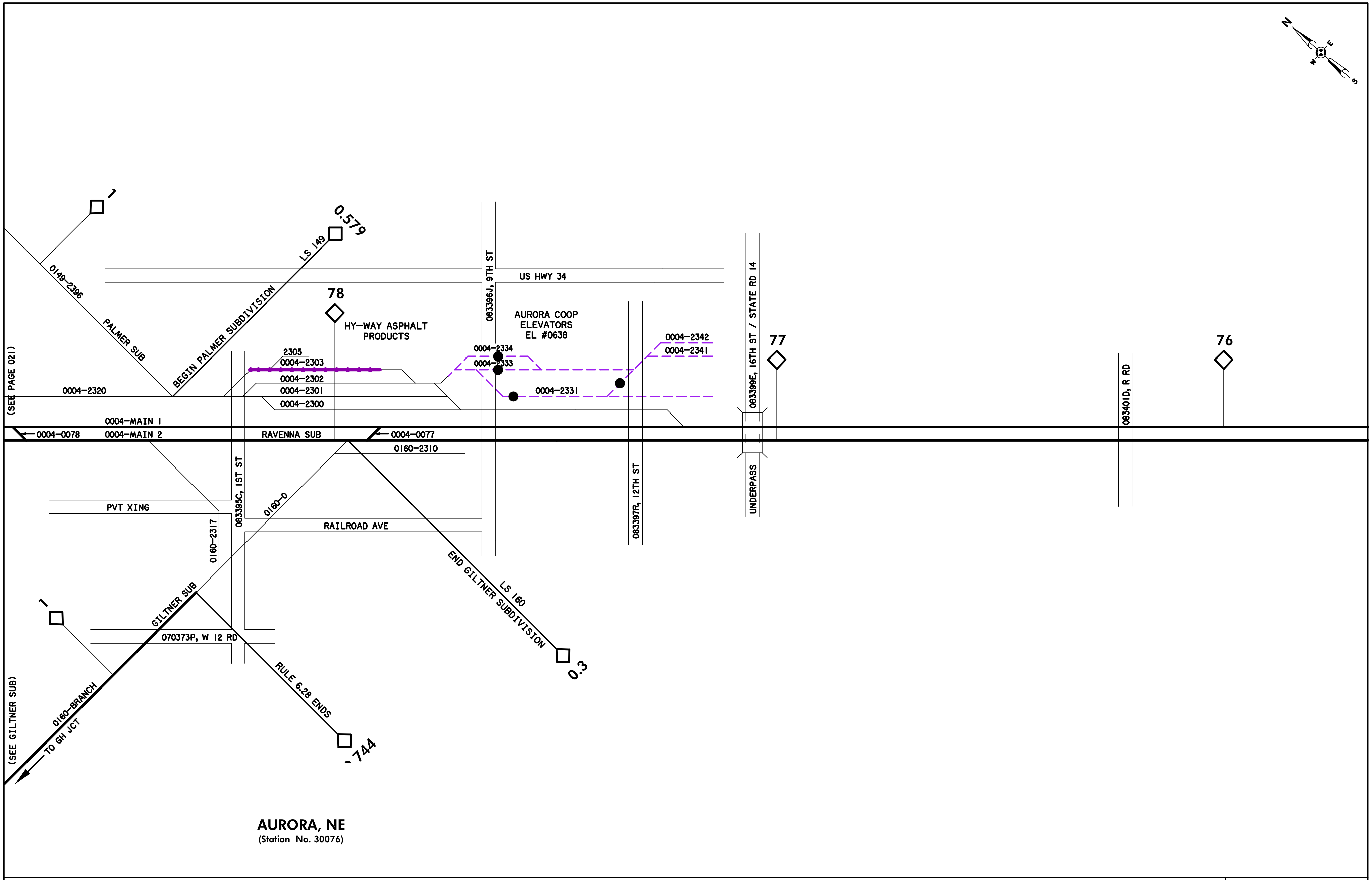
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: CURRNE
FSAC: 30080
REVISED: 6/2/2015
TEAM: CURR23021.DGN
TRK CHT: RAV022.dgn

AURORA, NE
Ravenna Subdivision

← Ravenna, NE

Lincoln, NE →



BNSF RAILWAY

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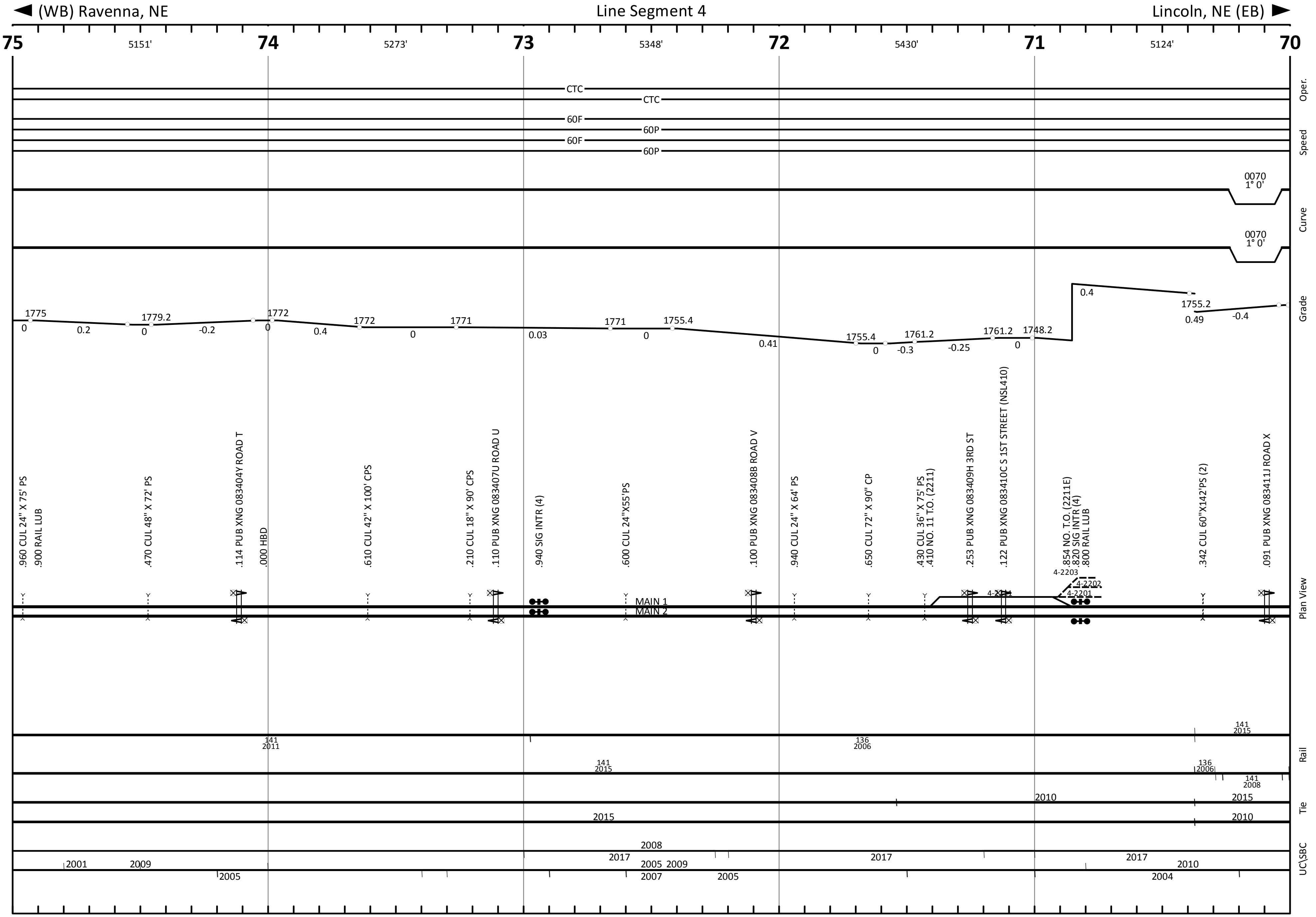
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ******
FSAC: *****
REVISED: 1/24/2018
TEAM: AURO23023.DGN
TRK CHT: RAV023.DGN



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

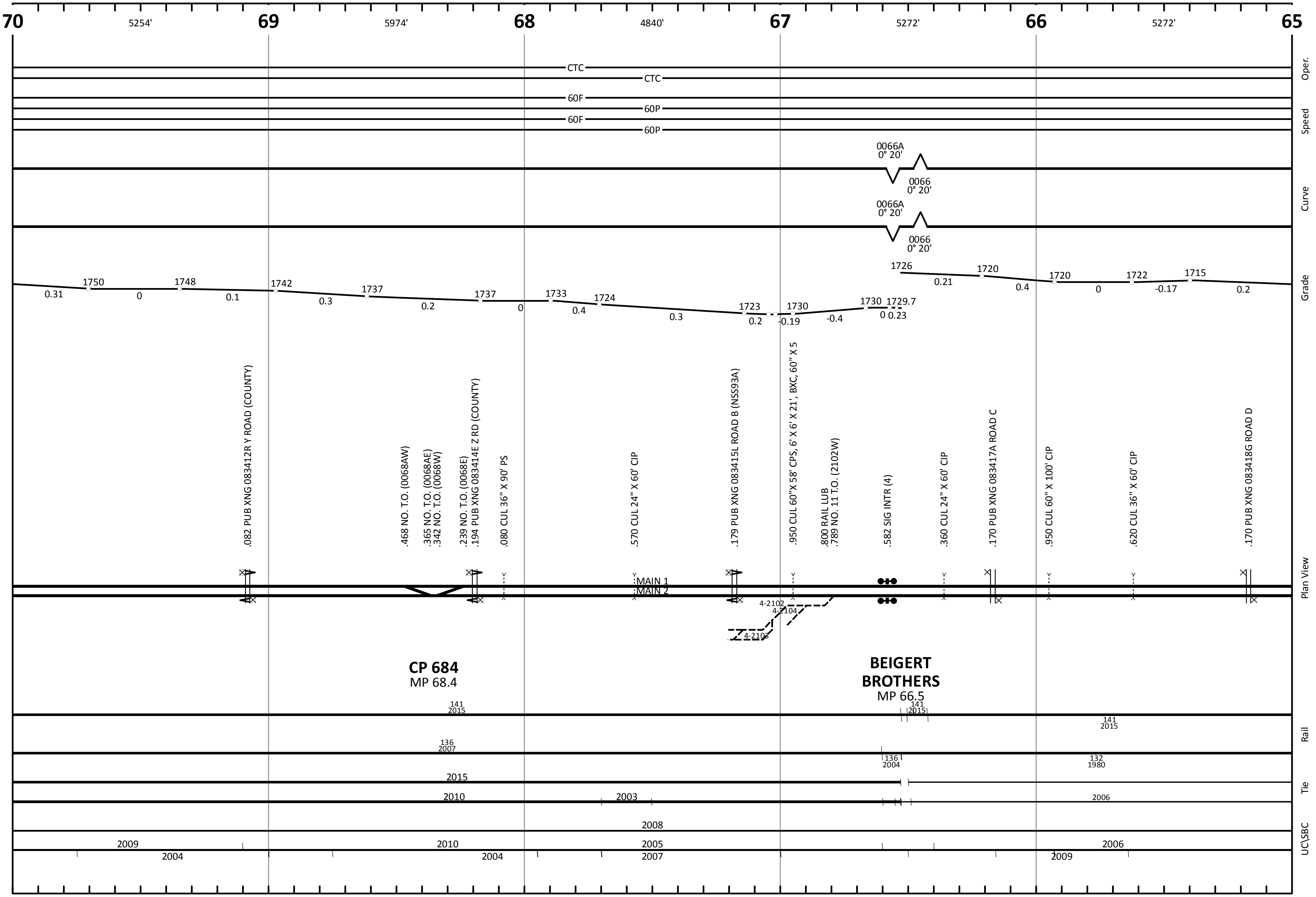
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

◄ (WB) Ravenna, NE　　Line Segment 4　　Lincoln, NE (EB) ►



System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

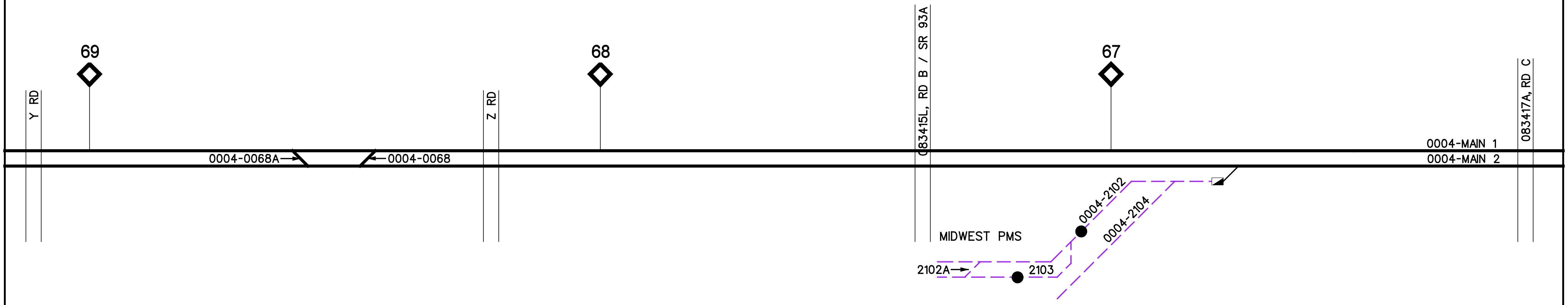
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 22, 2018

BEIGART BROTHERS, NE

Ravenna Subdivision

← Ravenna, NE

Hobson, NE →



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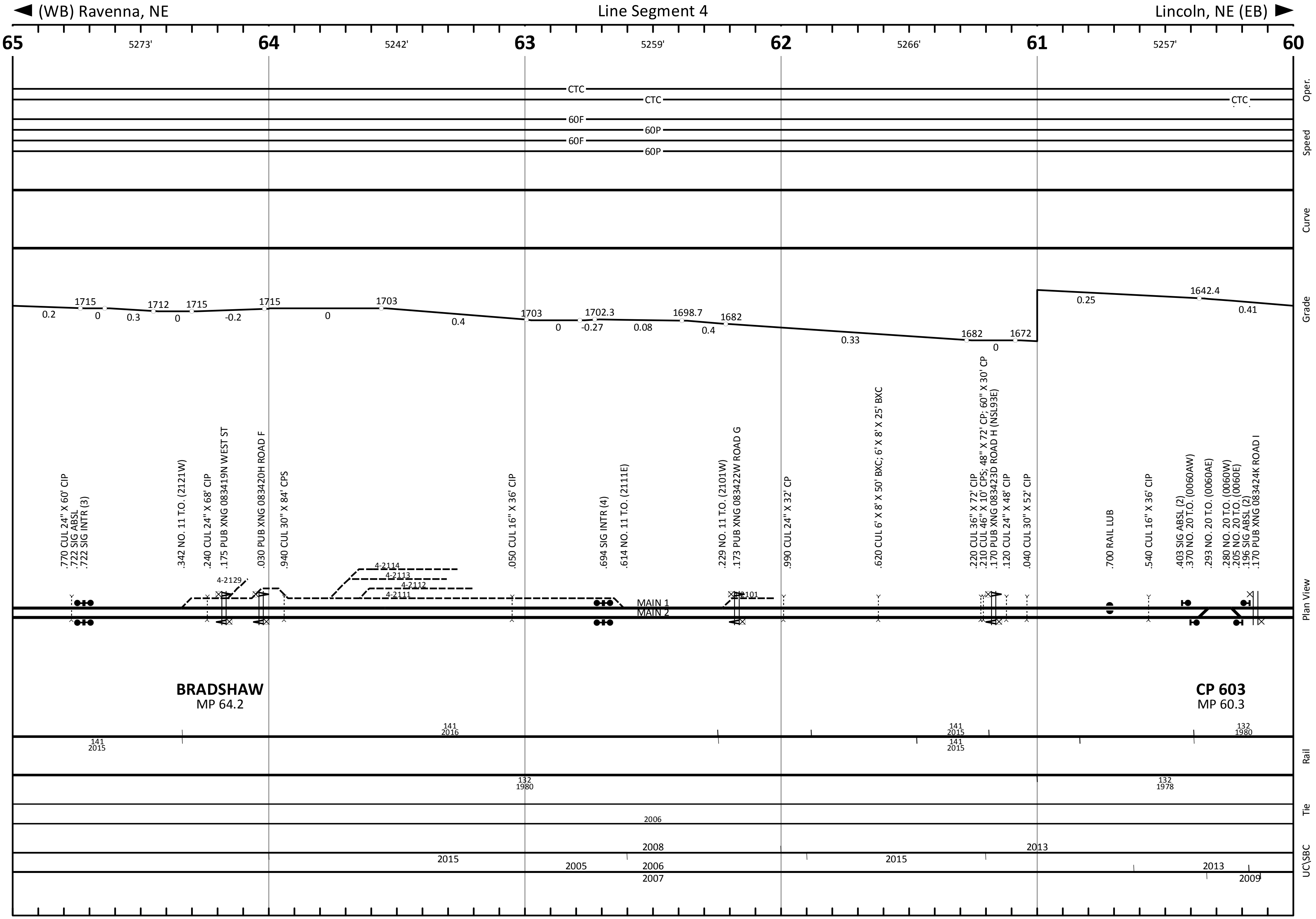
———	BNSF OWNED & MAINT	—+—+—	JOINT FACILITIES
—◆—◆—	INDUSTRY OWNED & BNSF MAINT	▬▬▬	TRACKAGE RIGHTS
– – – –	IND OWNED & MAINT	—+—+—+—	FOREIGN TRACK
●—●—●—●	INDUSTRY MAINT & BNSF OWNED (LEASE)		
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT		
◪	DERAIL		

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ******
FSAC: *****
REVISED: 4/30/2015
TEAM: BEIG21027.DGN
TRK CHT: RAV026.dgn
TEAM PG 027



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

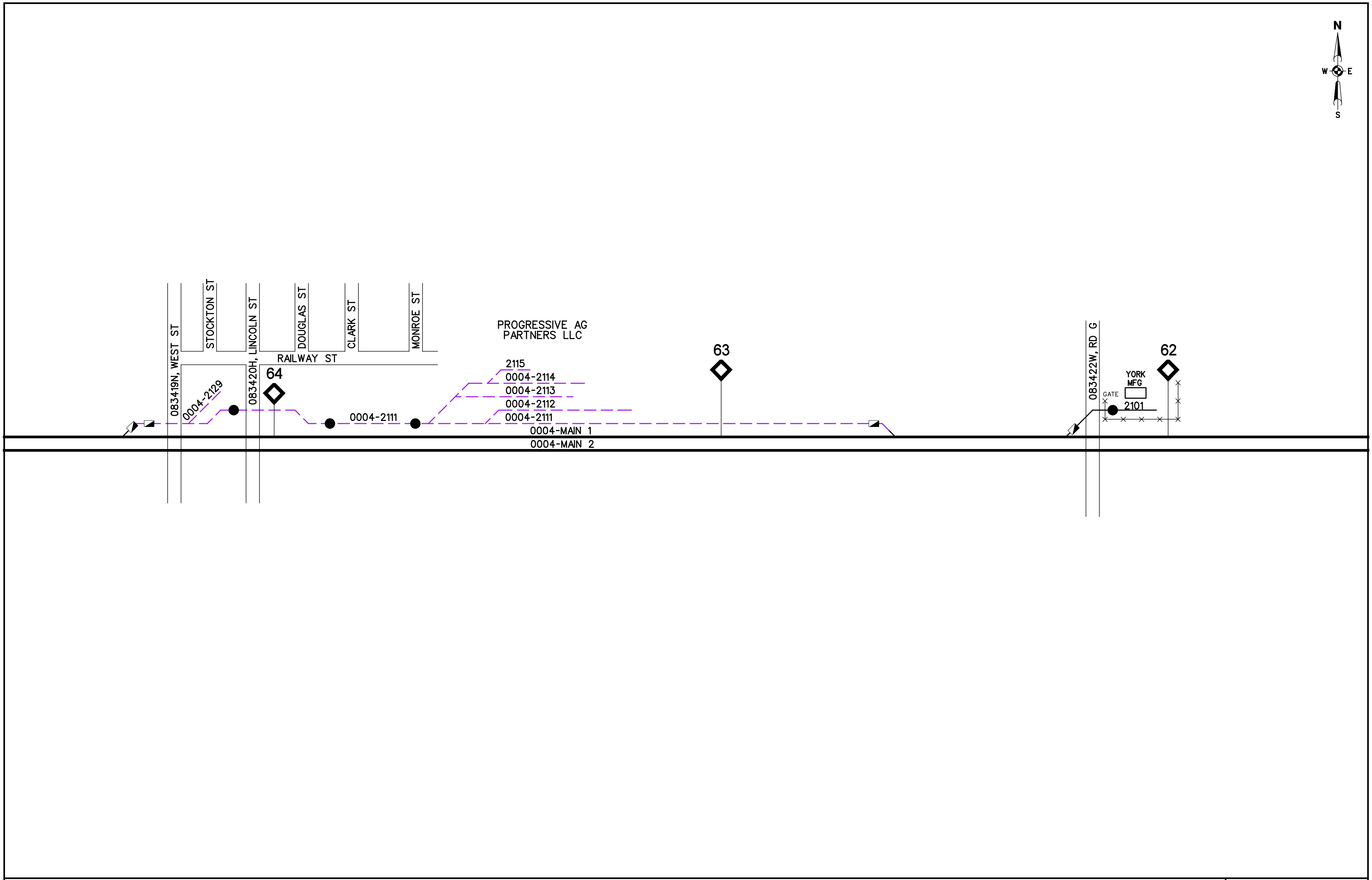
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

BRADSHAW, NE
Ravenna Subdivision

← Ravenna, NE

Hobson, NE →



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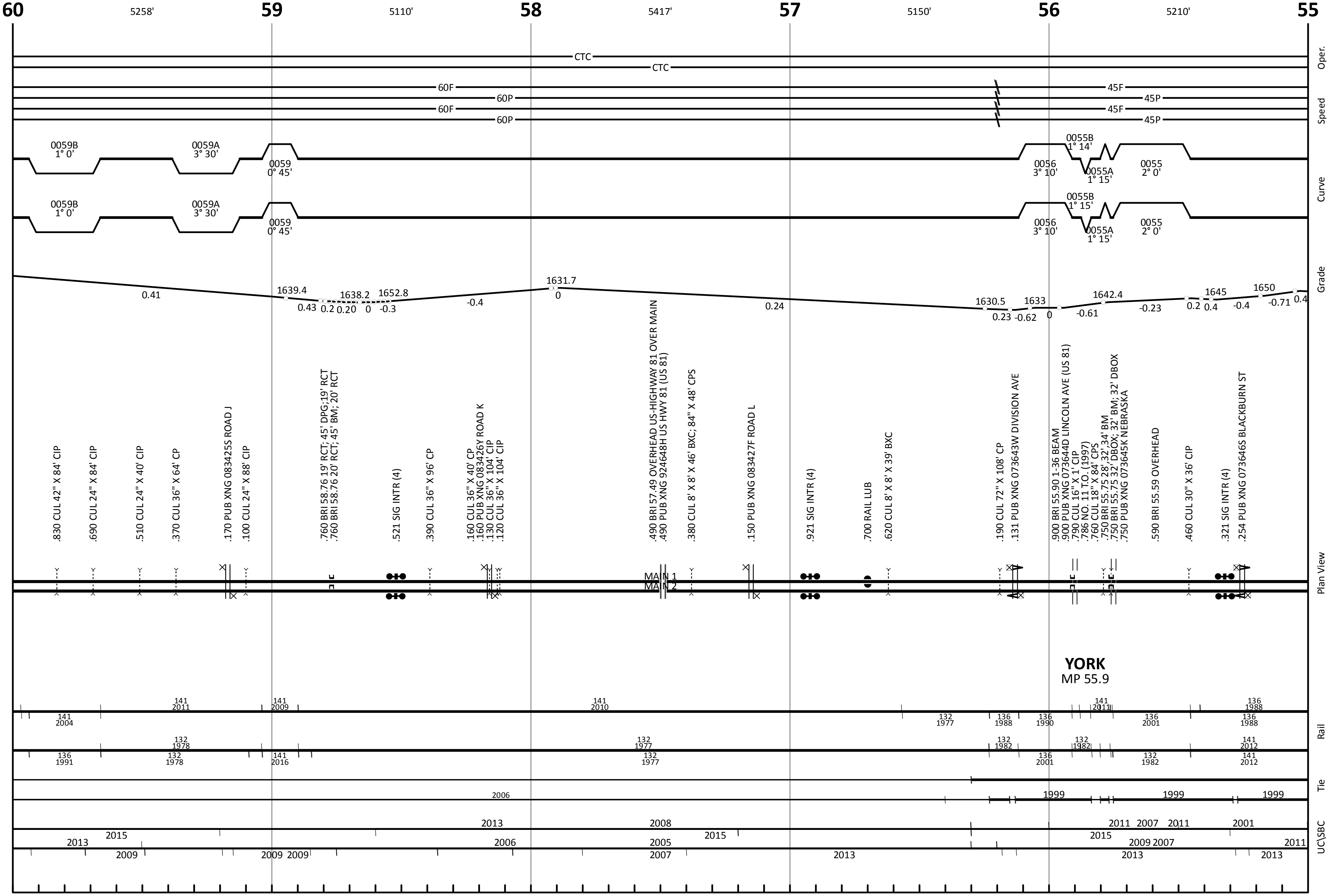
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: BRADSH
FSAC: 30063
REVISED: 11/7/2014
TEAM: BRAD21029.DGN
TRK CHT: RAV028.DGN

◄ (WB) Ravenna, NE Line Segment 4 Lincoln, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

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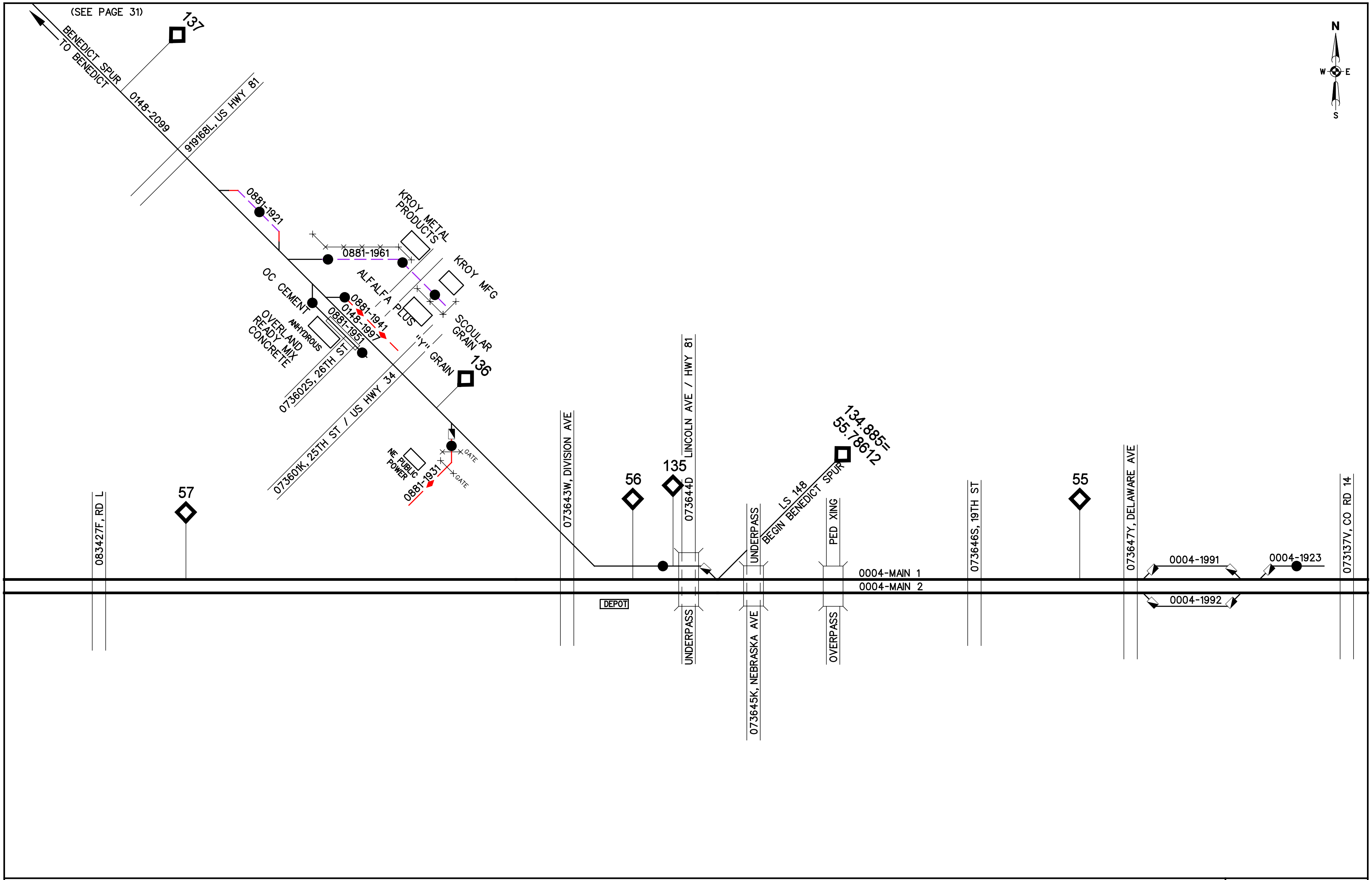
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

YORK, NE
Ravenna Subdivision

← Ravenna, NE Hobson, NE →



BNSF RAILWAY

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INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
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◪ DERAIL

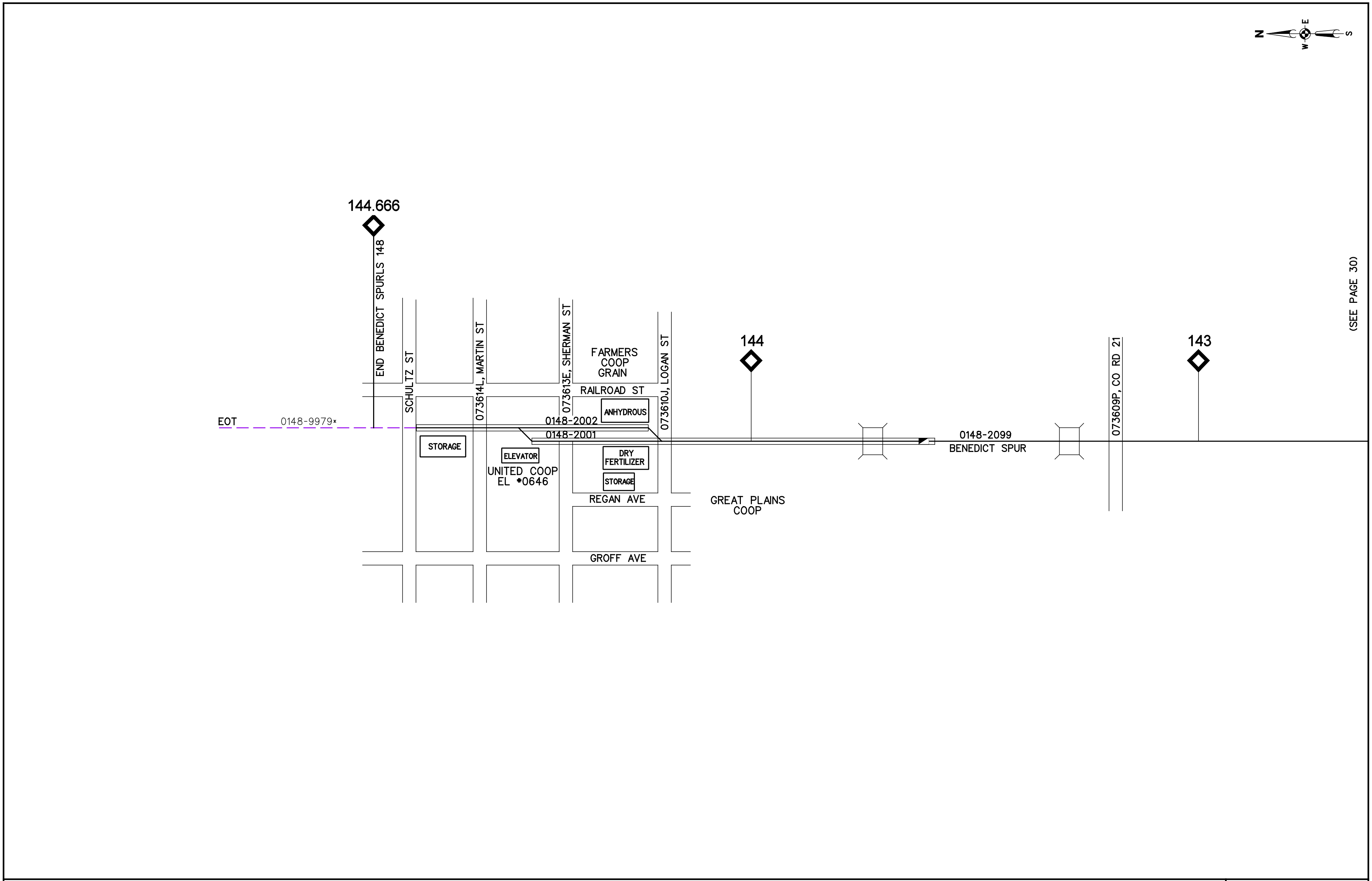
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: YORKNE
FSAC: 30055
REVISED: 11/7/2014
TEAM: YORK19031.DGN
TRK CHT: RAV030.DGN
TEAM PG 031

BENEDICT, NE
Ravenna Subdivision

York, NE →



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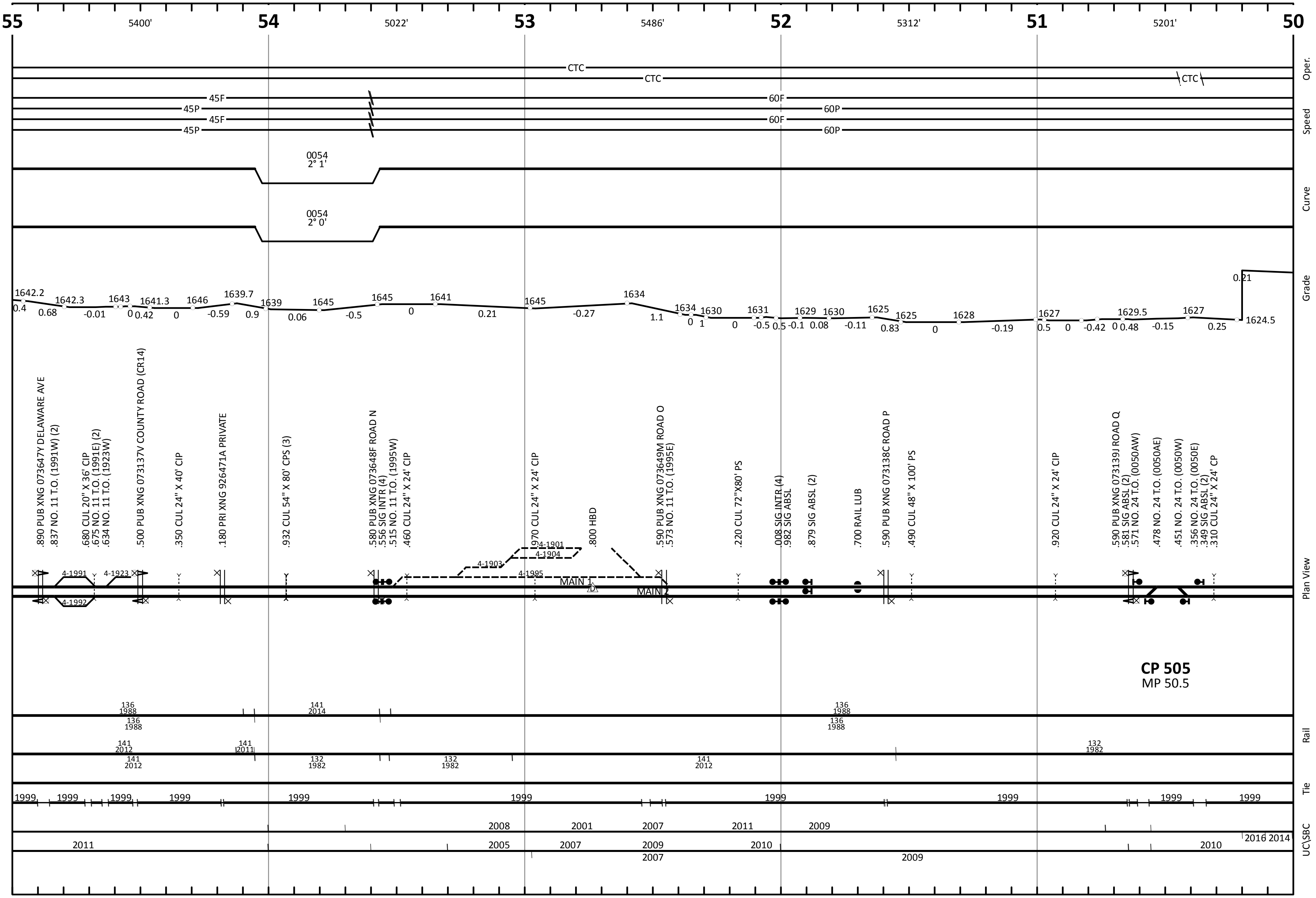
─┼┼─┼┼─	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: BENEDI
FSAC: 83209
REVISED: 11/7/2014
TEAM: BENE20035.DGN
TRK CHT: RAV031.DGN

◄ (WB) Ravenna, NE Line Segment 4 Lincoln, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

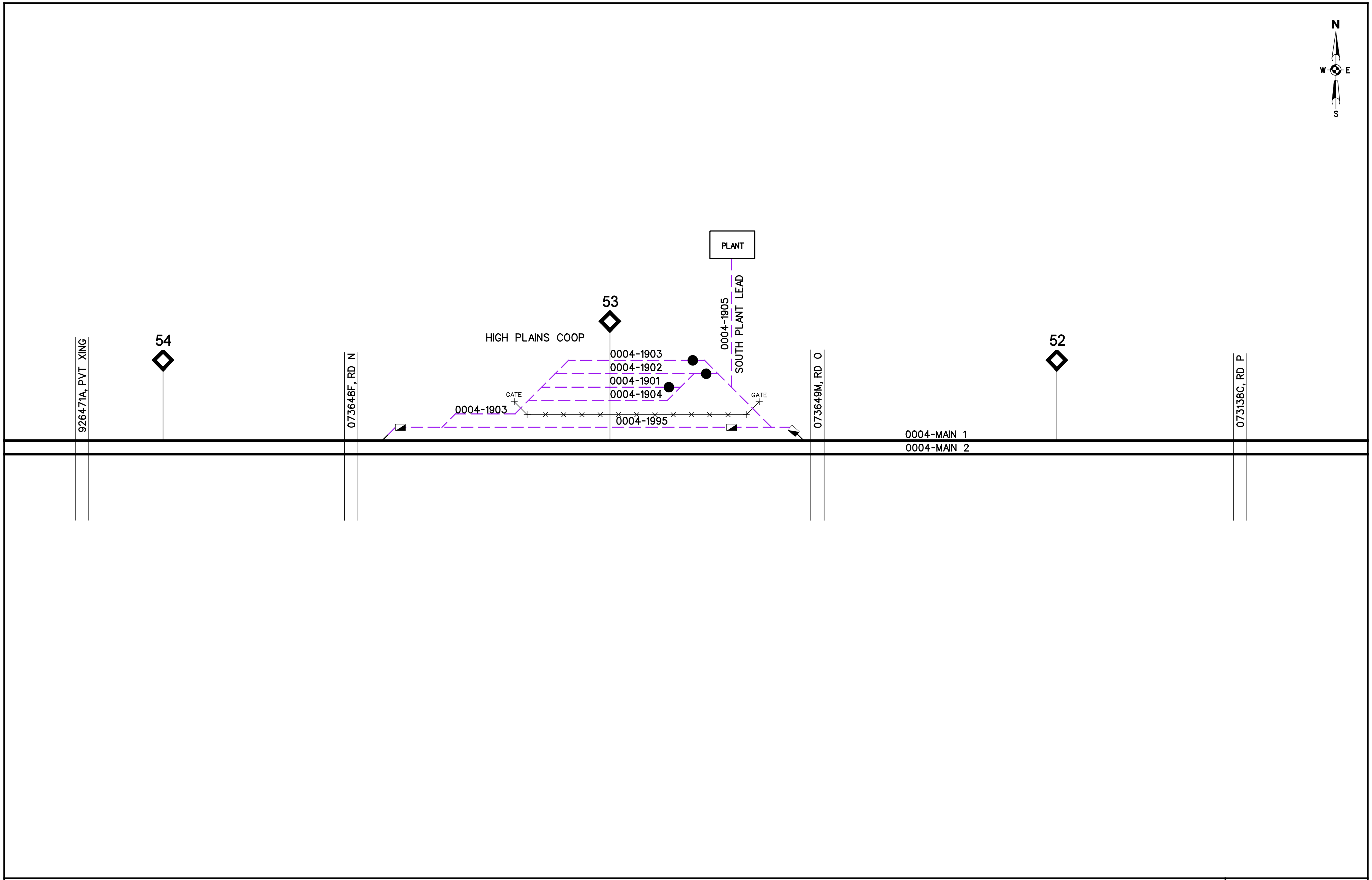
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

YORK, NE
Ravenna Subdivision

← Ravenna, NE

Hobson, NE →



BNSF RAILWAY

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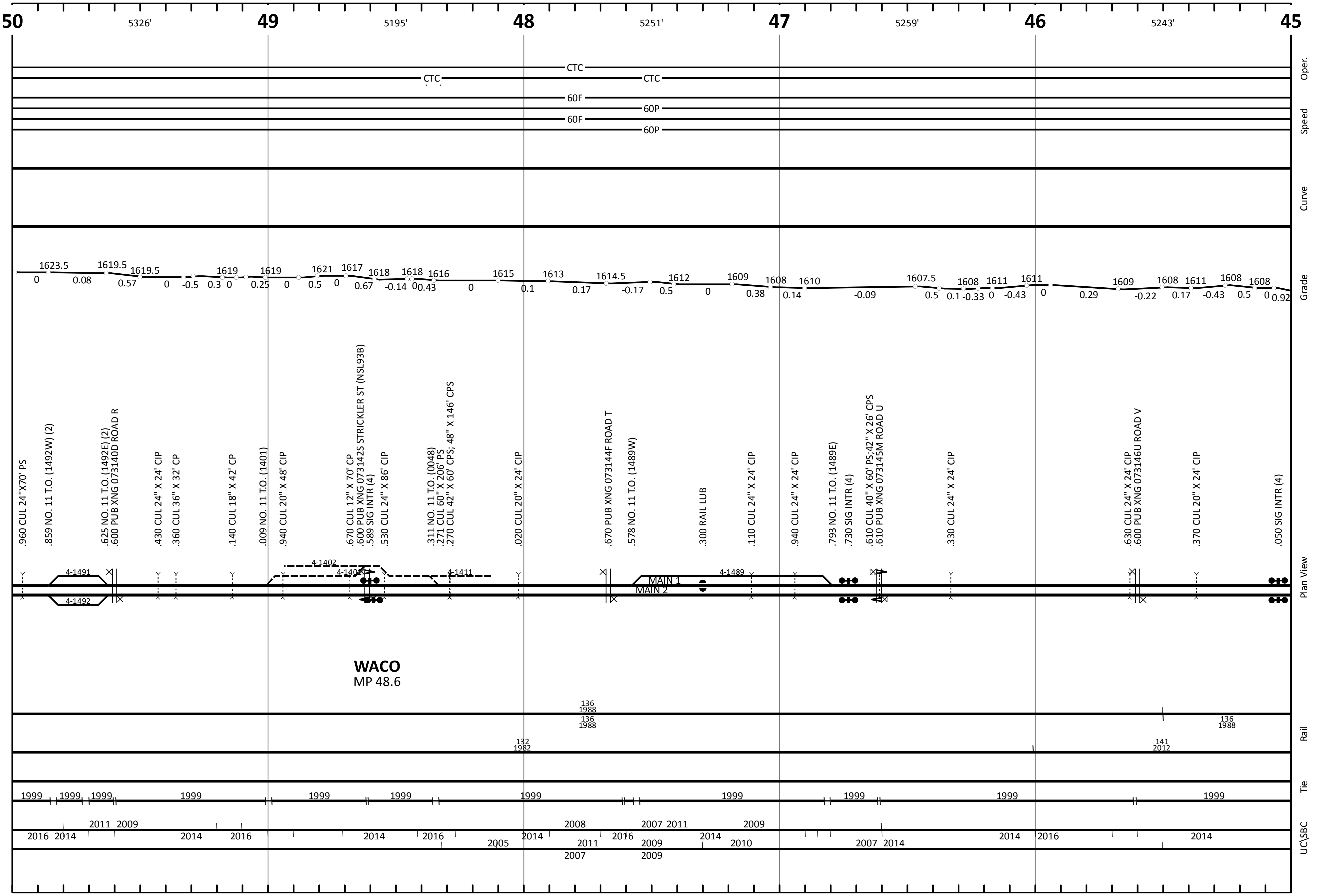
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

———	BNSF OWNED & MAINT	—┼—┼—	JOINT FACILITIES
—◆—◆—	INDUSTRY OWNED & BNSF MAINT	▬▬	TRACKAGE RIGHTS
- - - -	IND OWNED & MAINT	┼┼┼┼	FOREIGN TRACK
—●—●—●—	INDUSTRY MAINT & BNSF OWNED (LEASE)		
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT		
◪	DERAIL		

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: YORKNE
FSAC: 30055
REVISED: 11/7/2014
TEAM: YORK19033.DGN
TRK CHT: RAV033.DGN
TEAM PG 033

◄ (WB) Ravenna, NE   Line Segment 4   Lincoln, NE (EB) ►



BNSF RAILWAY
System Maintenance and Planning

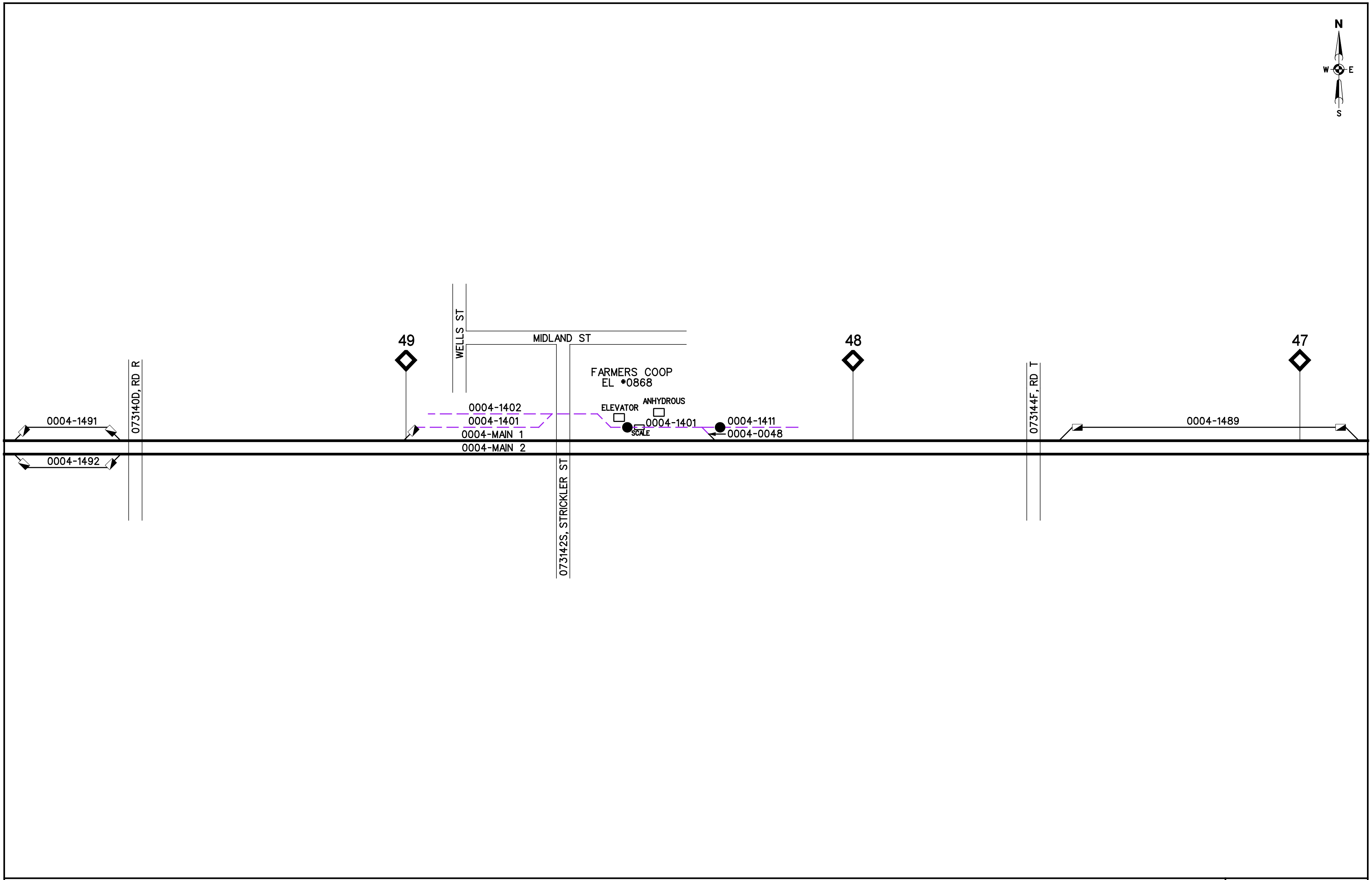
Ravenna Subdivision
Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 22, 2018

WACO, NE
Ravenna Subdivision

← Ravenna, NE

Hobson, NE →



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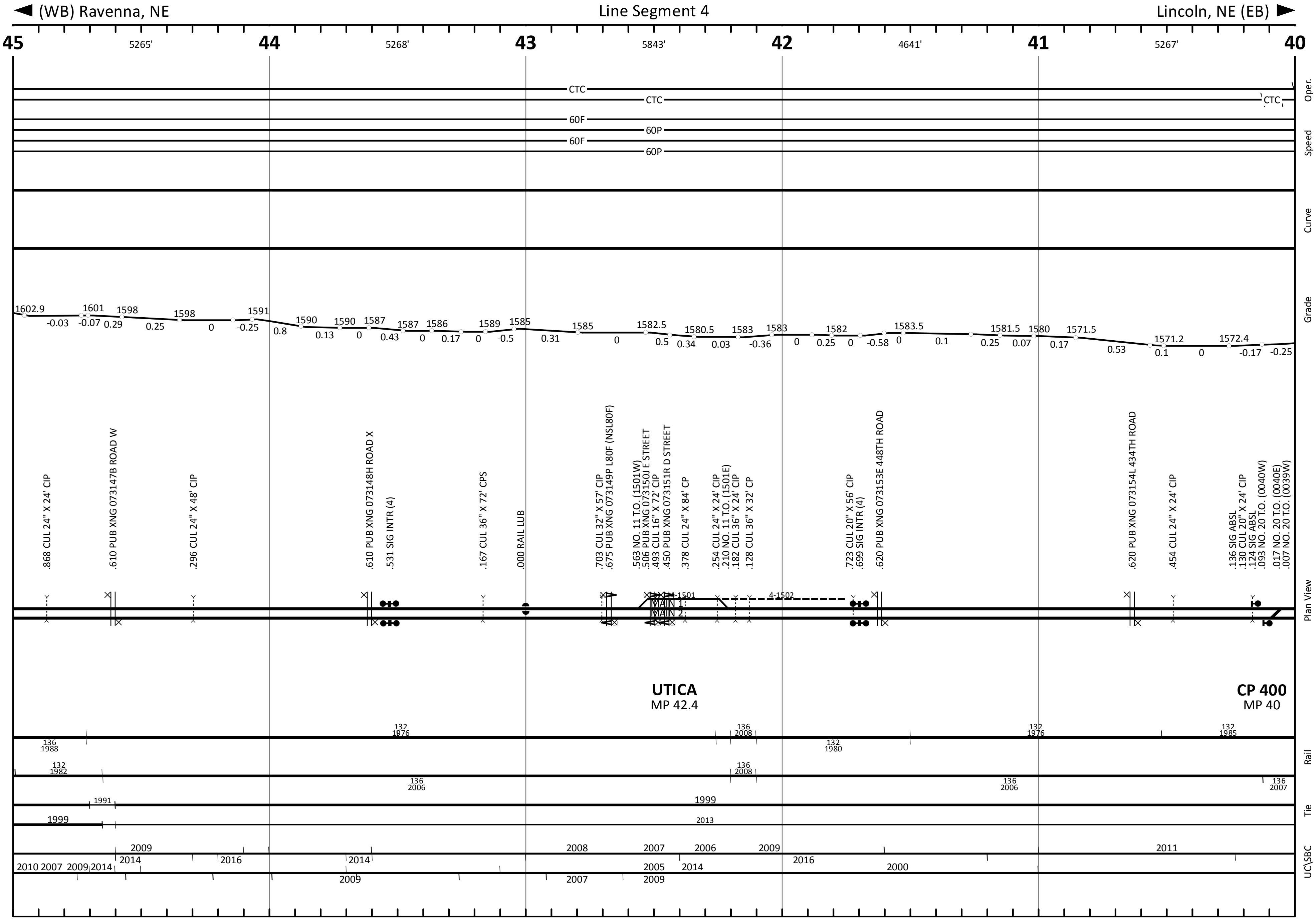
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: WACONE
FSAC: 30047
REVISED: 11/7/2014
TEAM: WACO14037.DGN
TRK CHT: RAV035.DGN



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

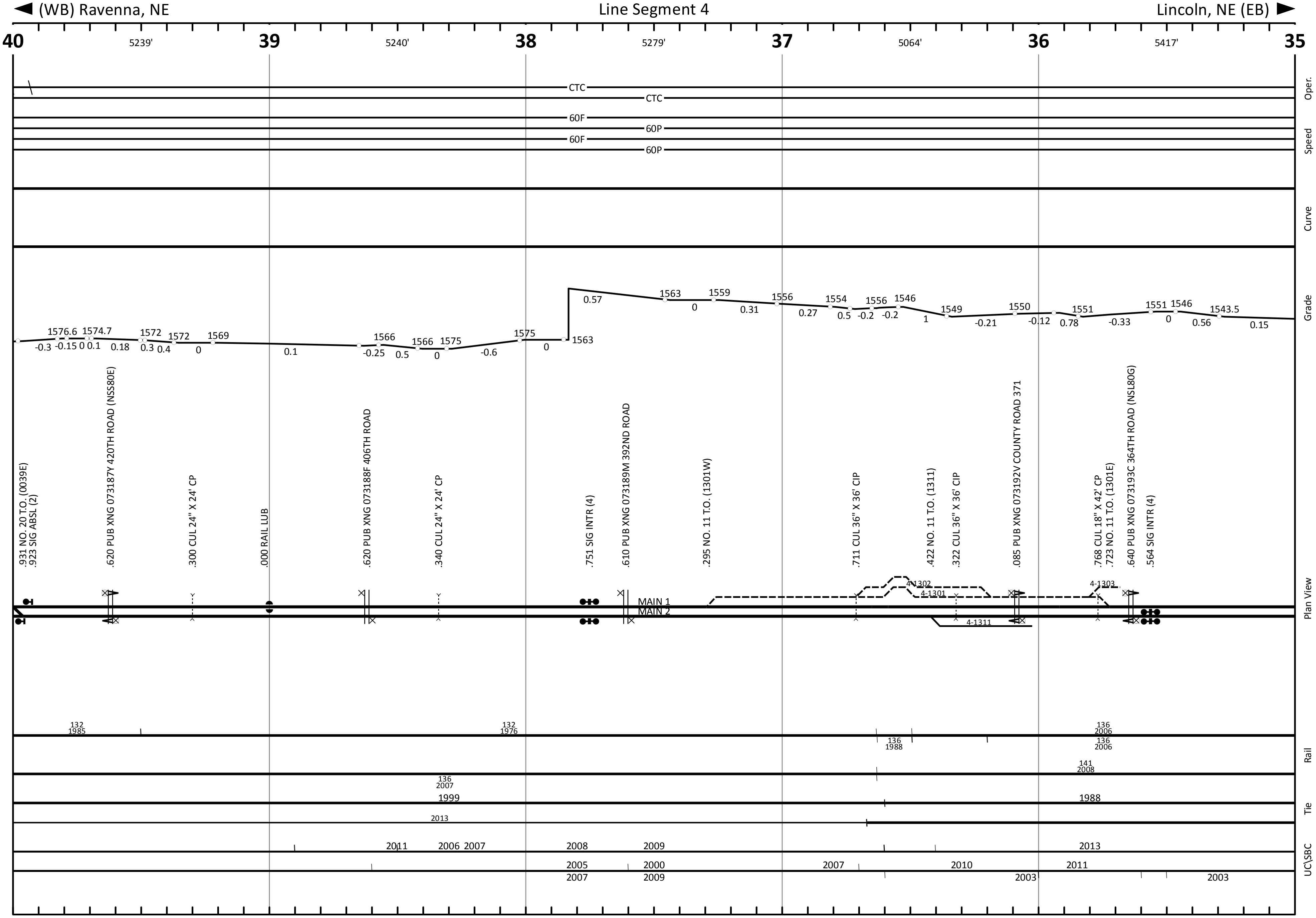
Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018 Page 36 of 44



BNSF RAILWAY

System Maintenance and Planning

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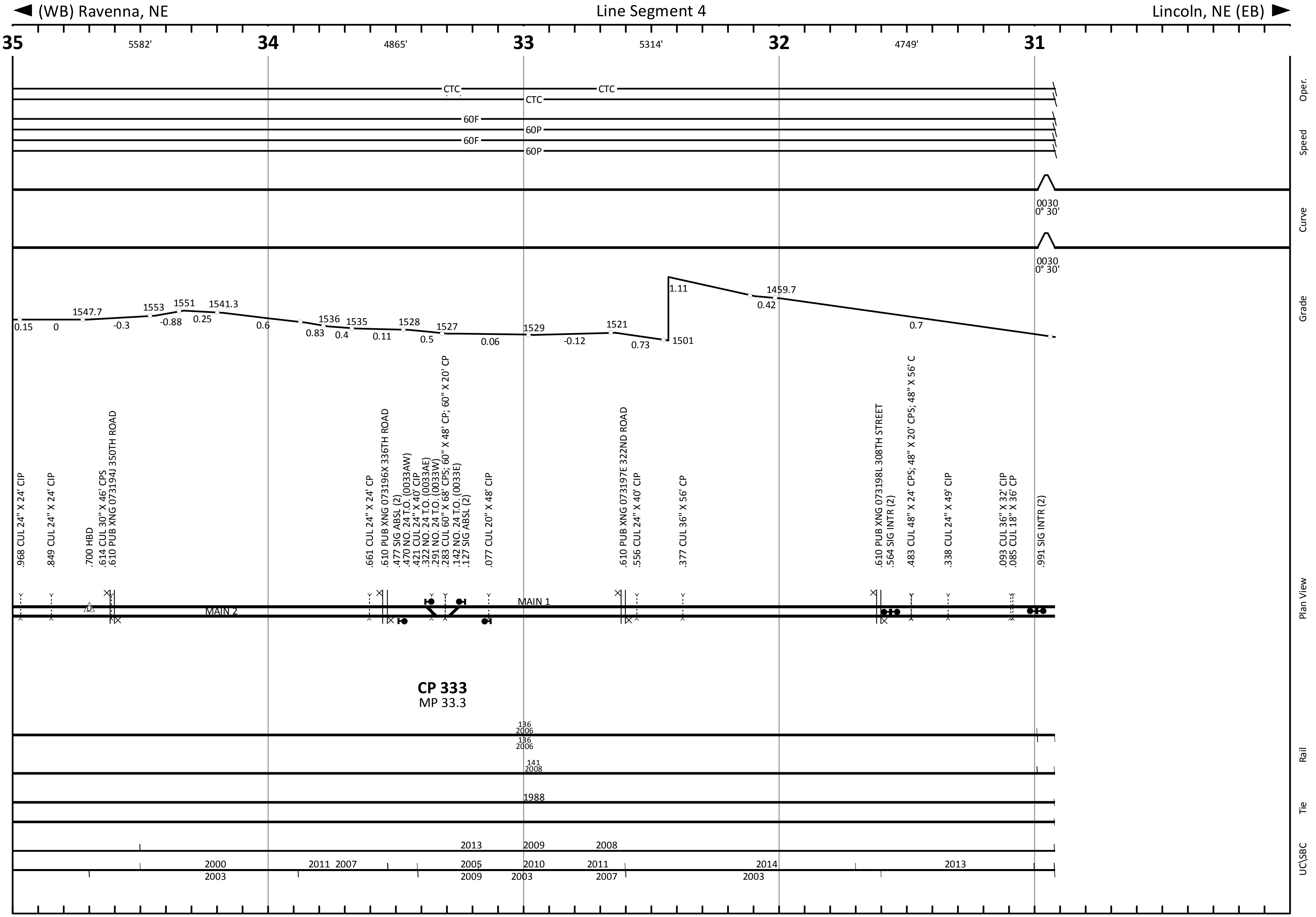
Revised to June 22, 2018



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

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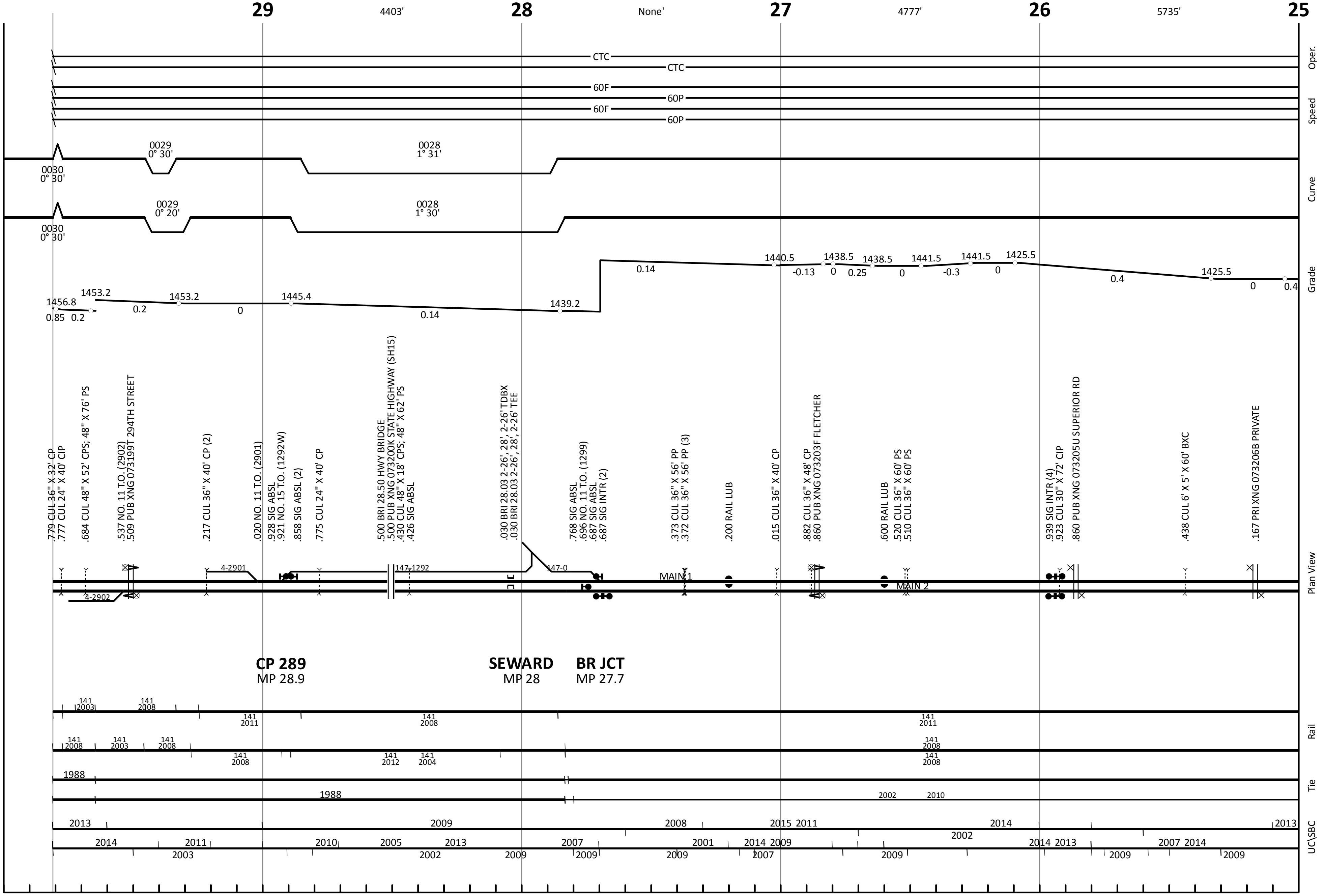
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

◄ (WB) Ravenna, NE	Line Segment 4	Lincoln, NE (EB) ►



BNSF RAILWAY

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Powder River Operating Division

Powder River East Engineering Division

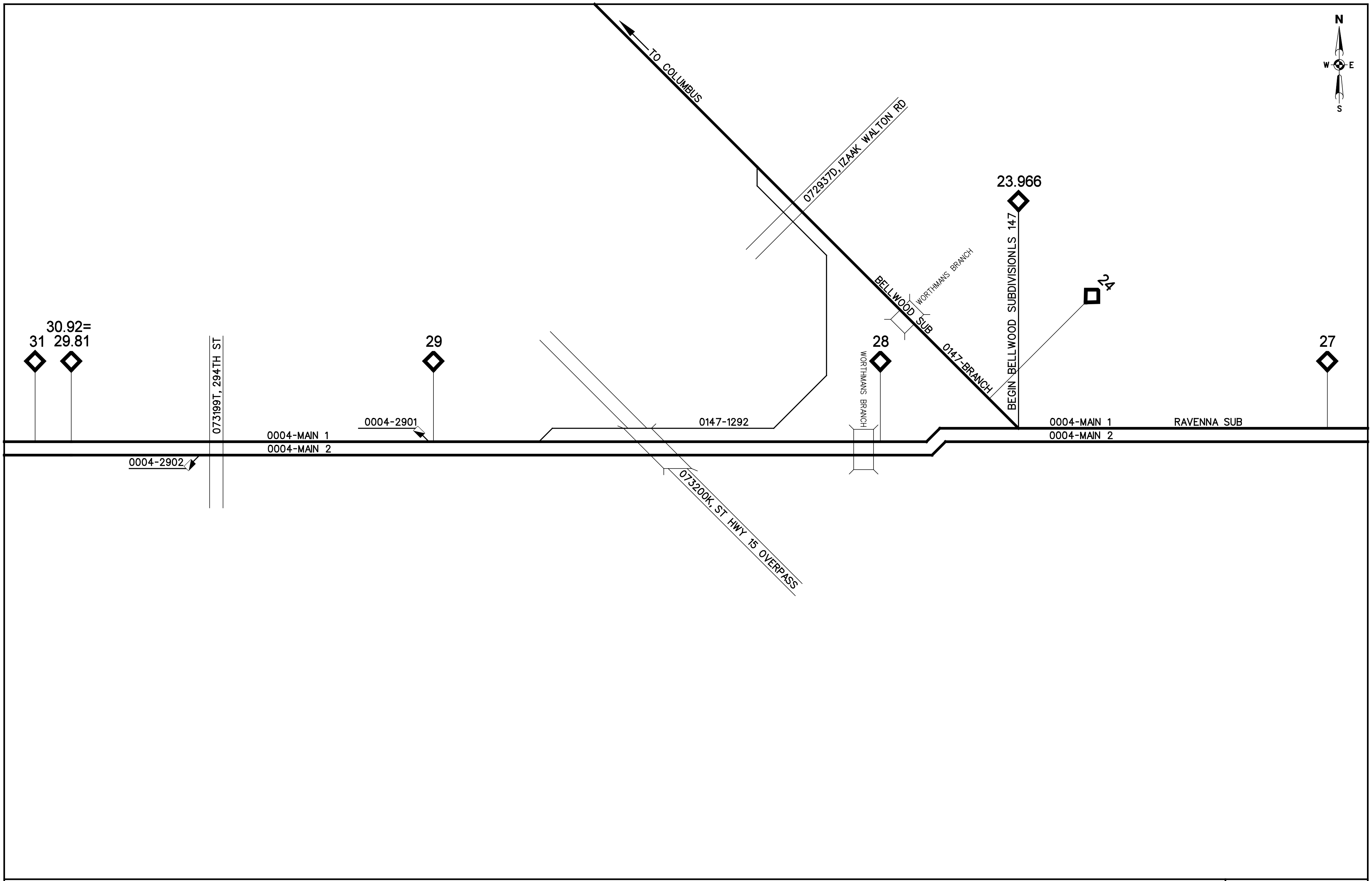
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

SEWARD, NE
Ravenna Subdivision

← Ravenna, NE

Lincoln, NE →



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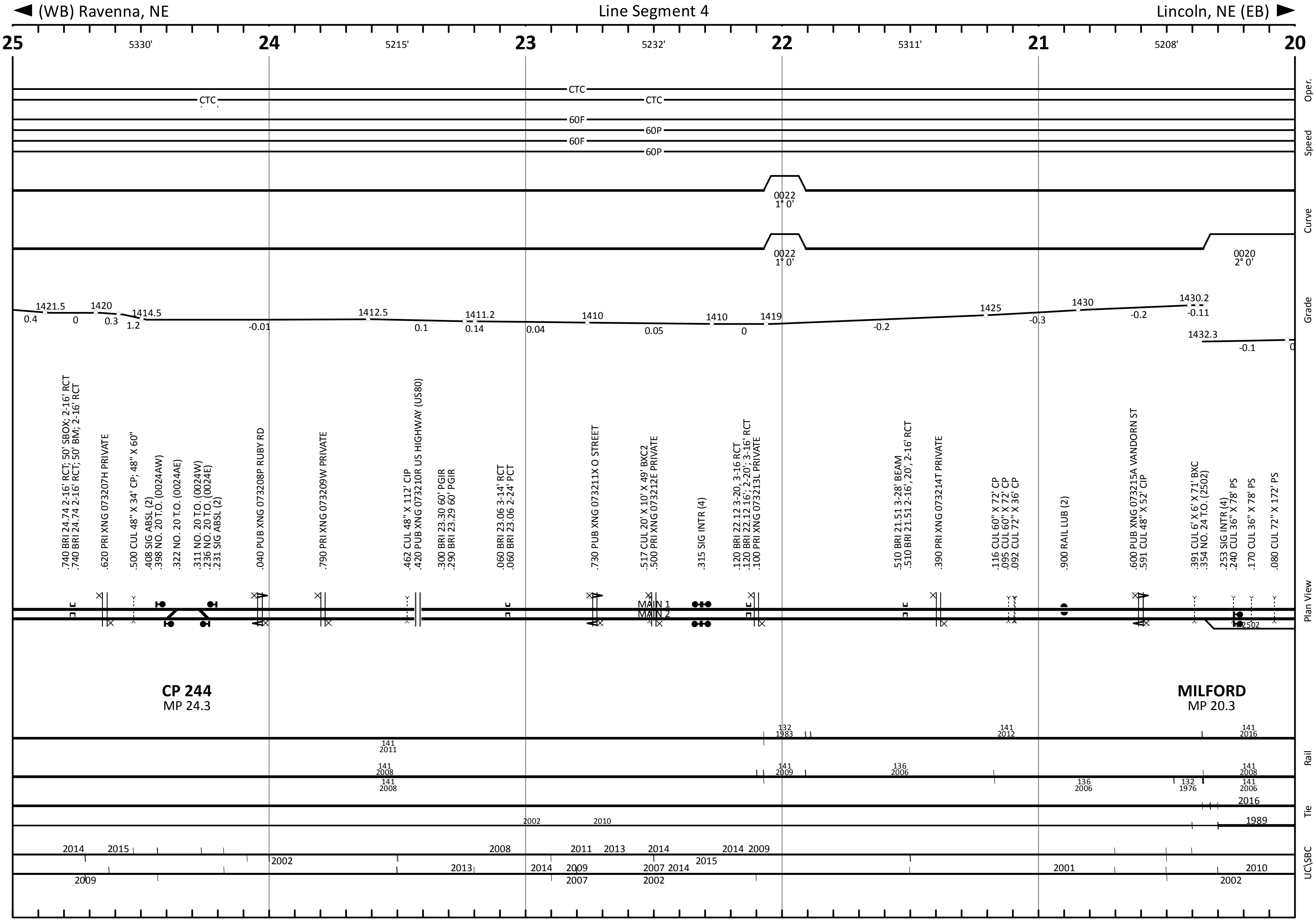
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: SEWANE
FSAC: 30029
REVISED: 11/7/2014
TEAM: SEWA29043.DGN
TRK CHT: RAV040.DGN
TEAM PG 043



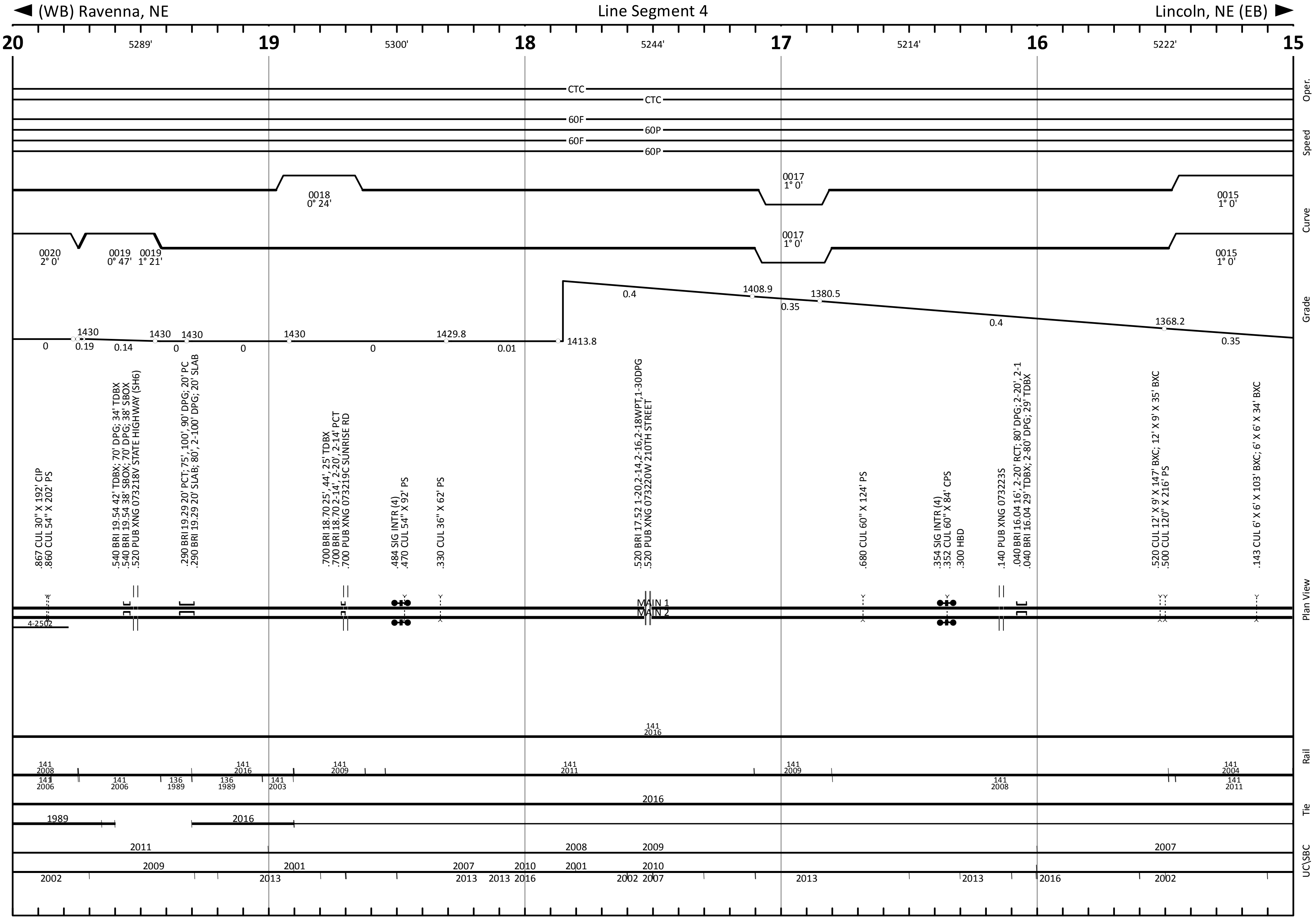
System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to June 22, 2018



BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

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Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

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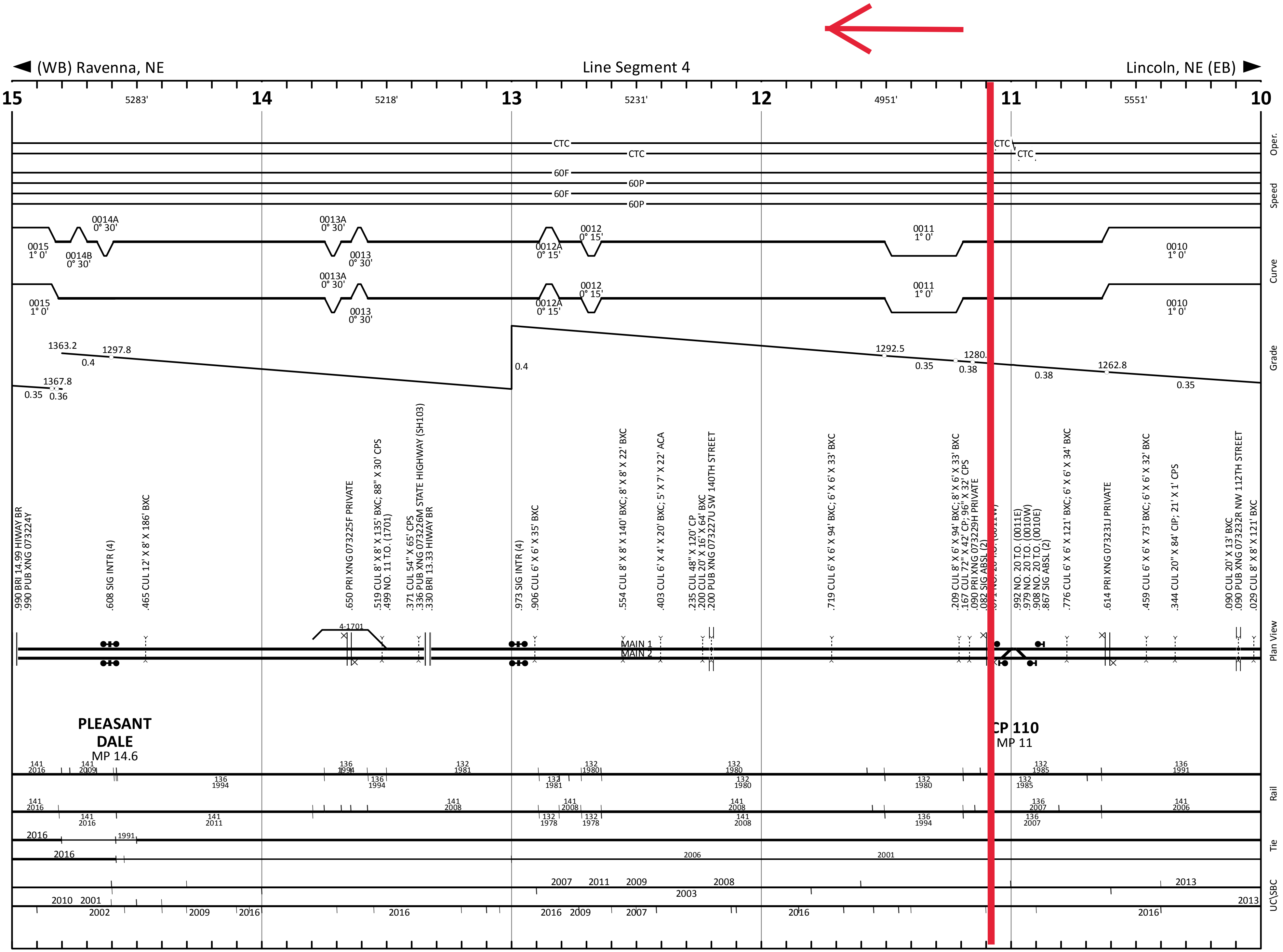


BNSF RAILWAY

System Maintenance and Planning

Ravenna Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to June 22, 2018

Track Chart
Sand Hills Subdivision

Ravenna, NE to East Alliance, NE

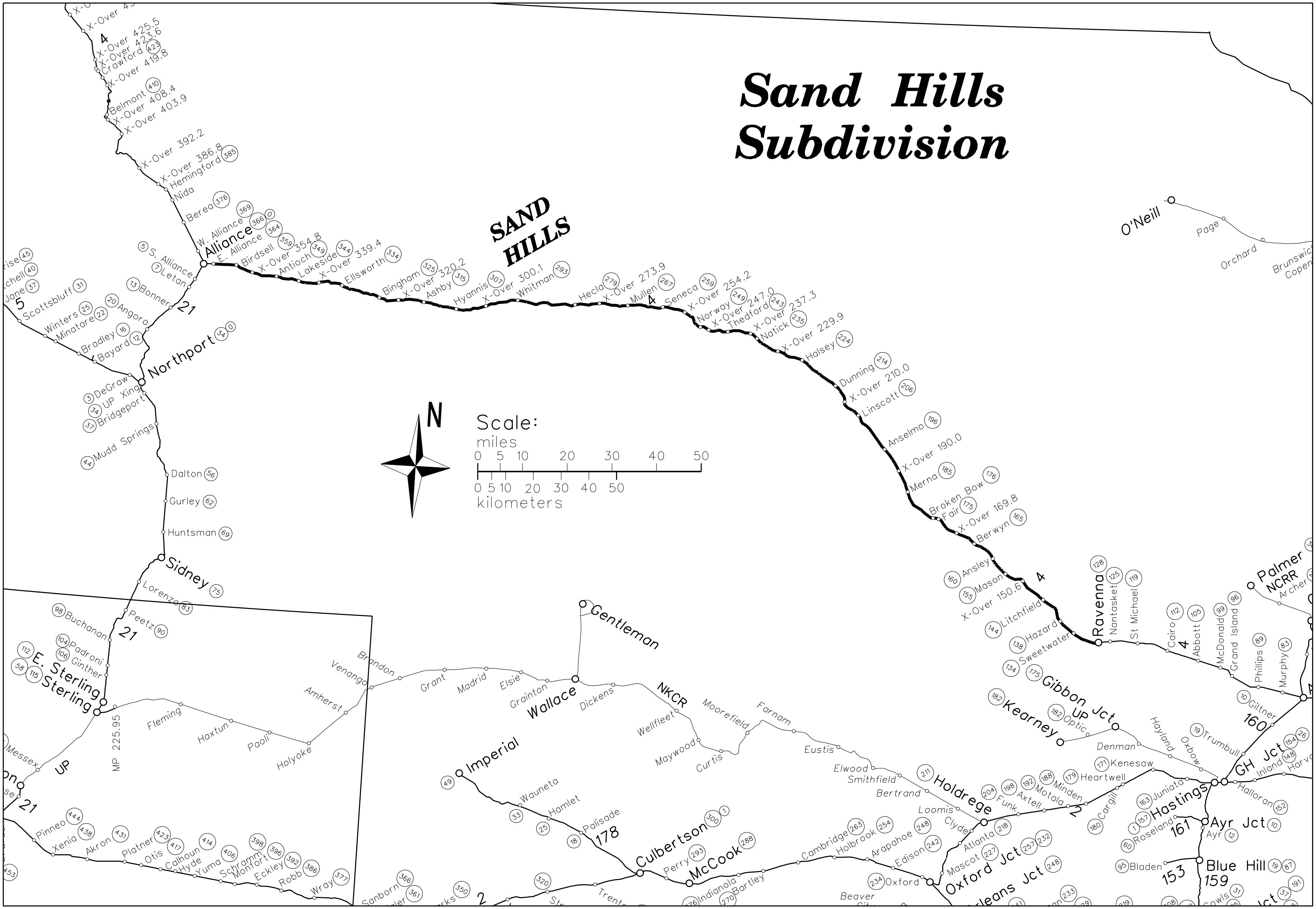
MP 128.2 to MP 364.1

See each page for latest revised date.

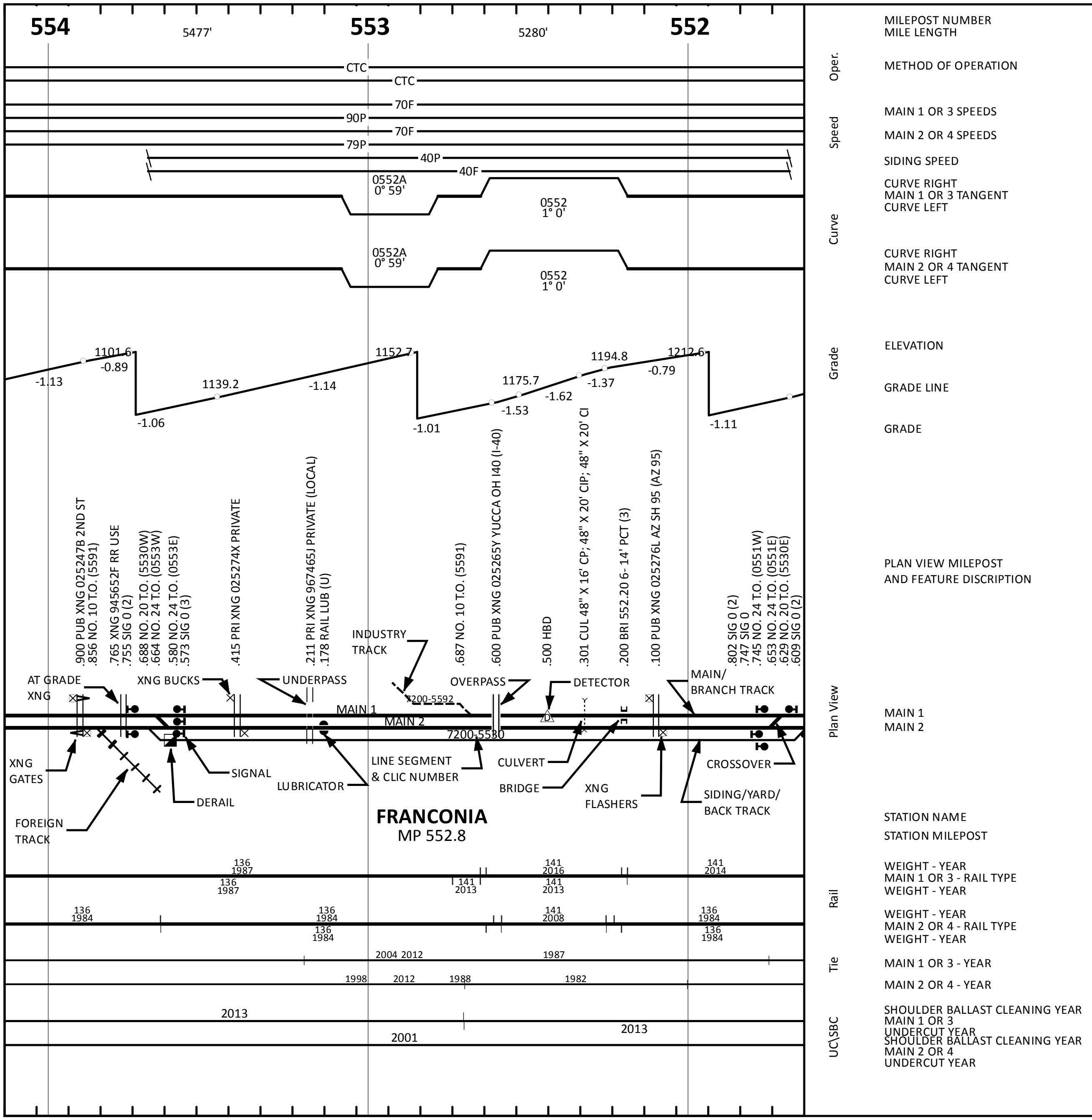
Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Sand Hills Subdivision



TRACK CHART FEATURE LEGEND



NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280') VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

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Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

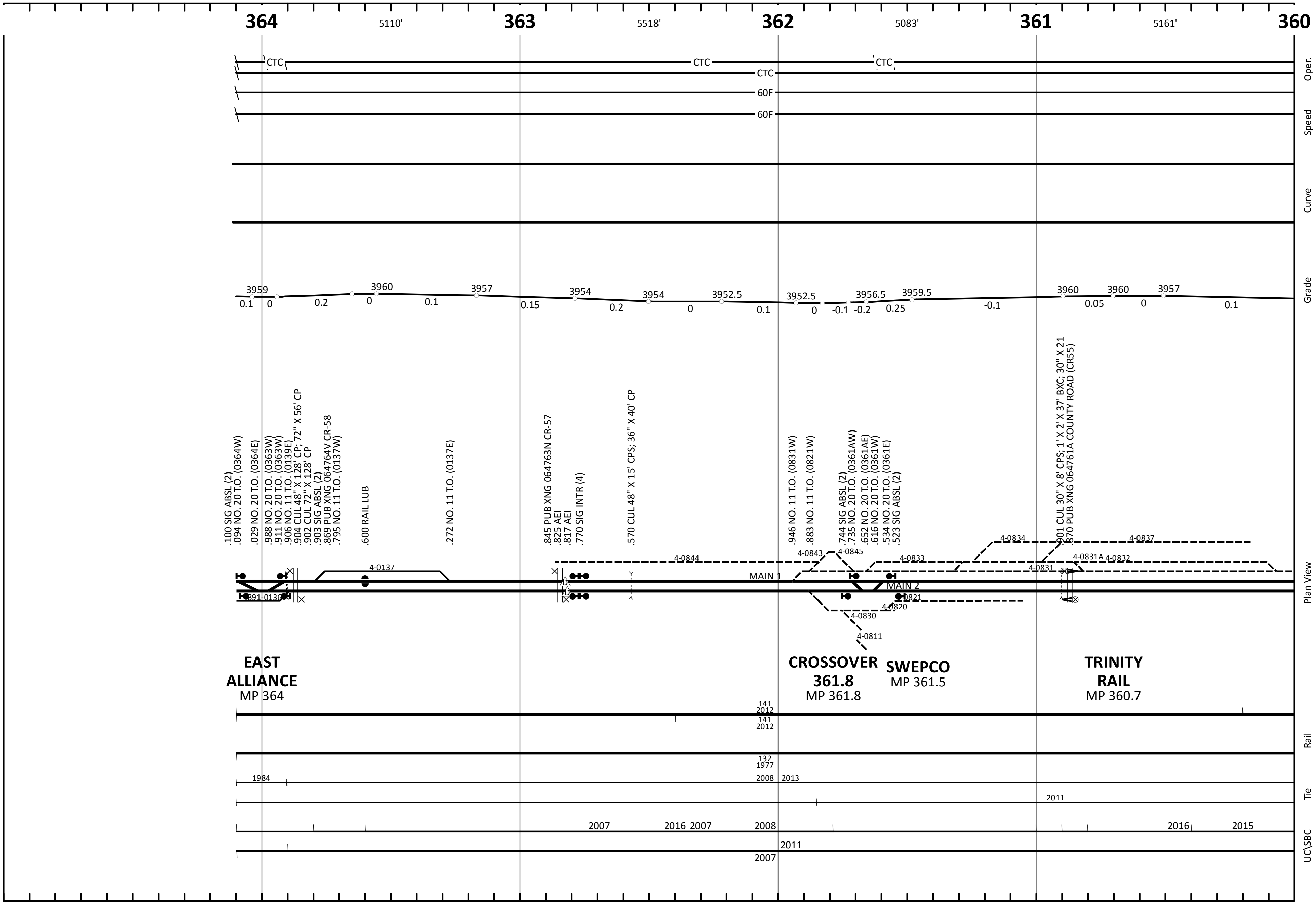
Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL

◄ (WB) EAST ALLIANCE, NE　　Line Segment 4　　RAVENNA, NE (EB) ►



System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division
Powder River East Engineering Division

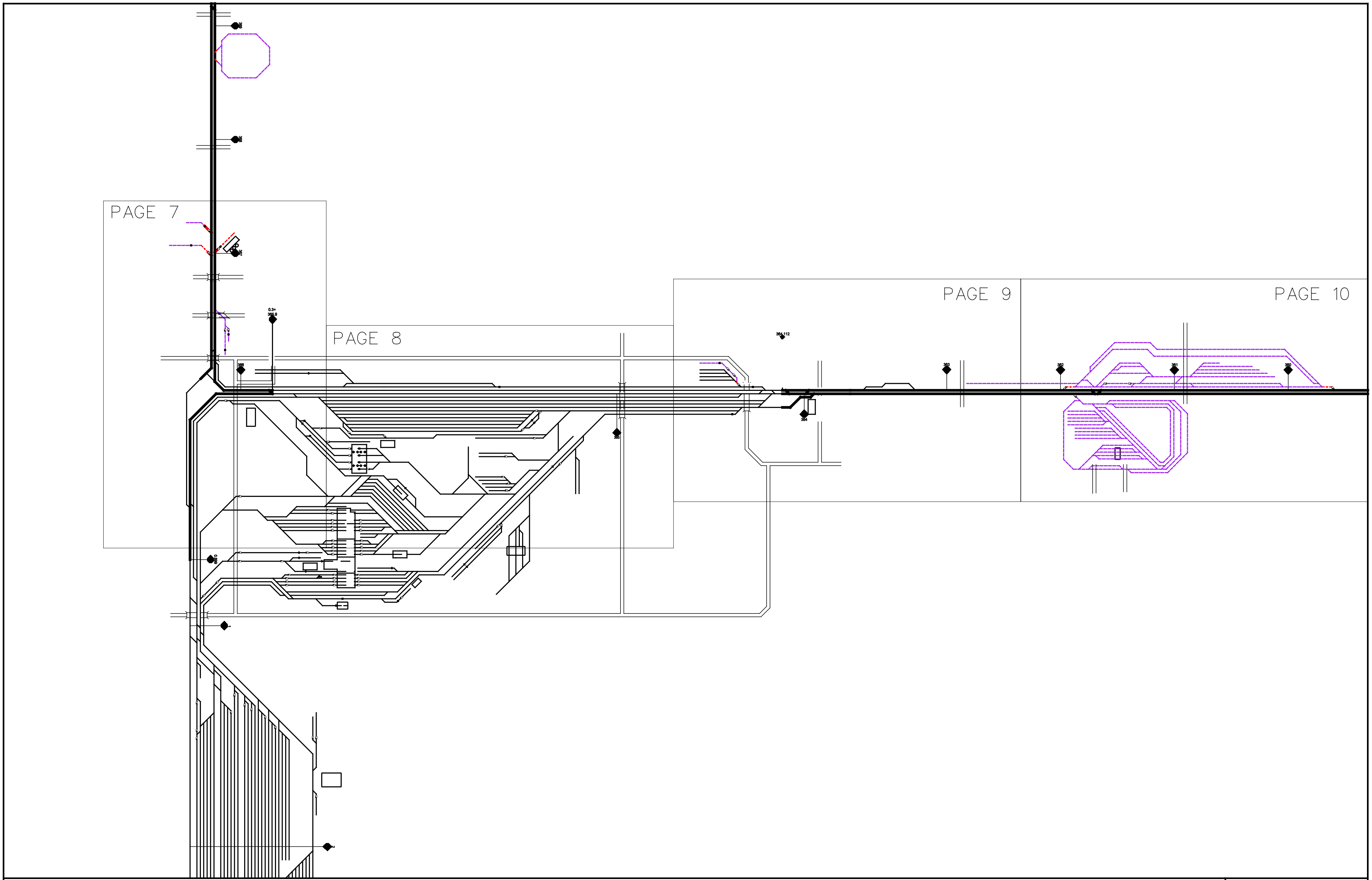
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 16, 2018　Page 5 of 61

ALLIANCE, NE

Sand Hills Subdivision

Ravenna, NE →



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INDUSTRY OWNED & BNSF MAINT
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◪ DERAIL

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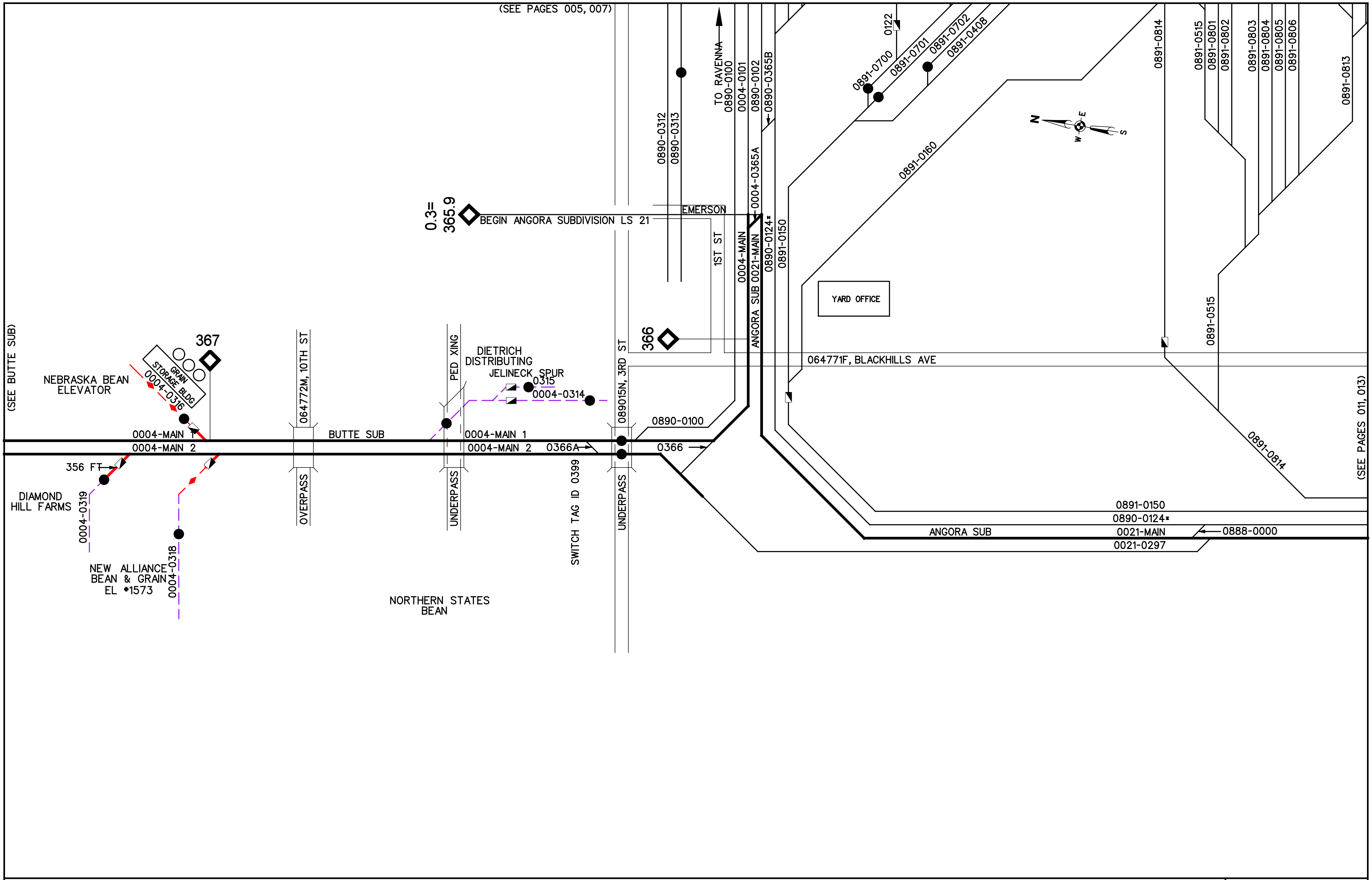
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/27/2016
TEAM: *********.DGN
TRK CHT: SAN006.DGN
TEAM PG ###

ALLIANCE, NE - Sand Hills Subdivision

← Edgemont, SD Sterling, CO →



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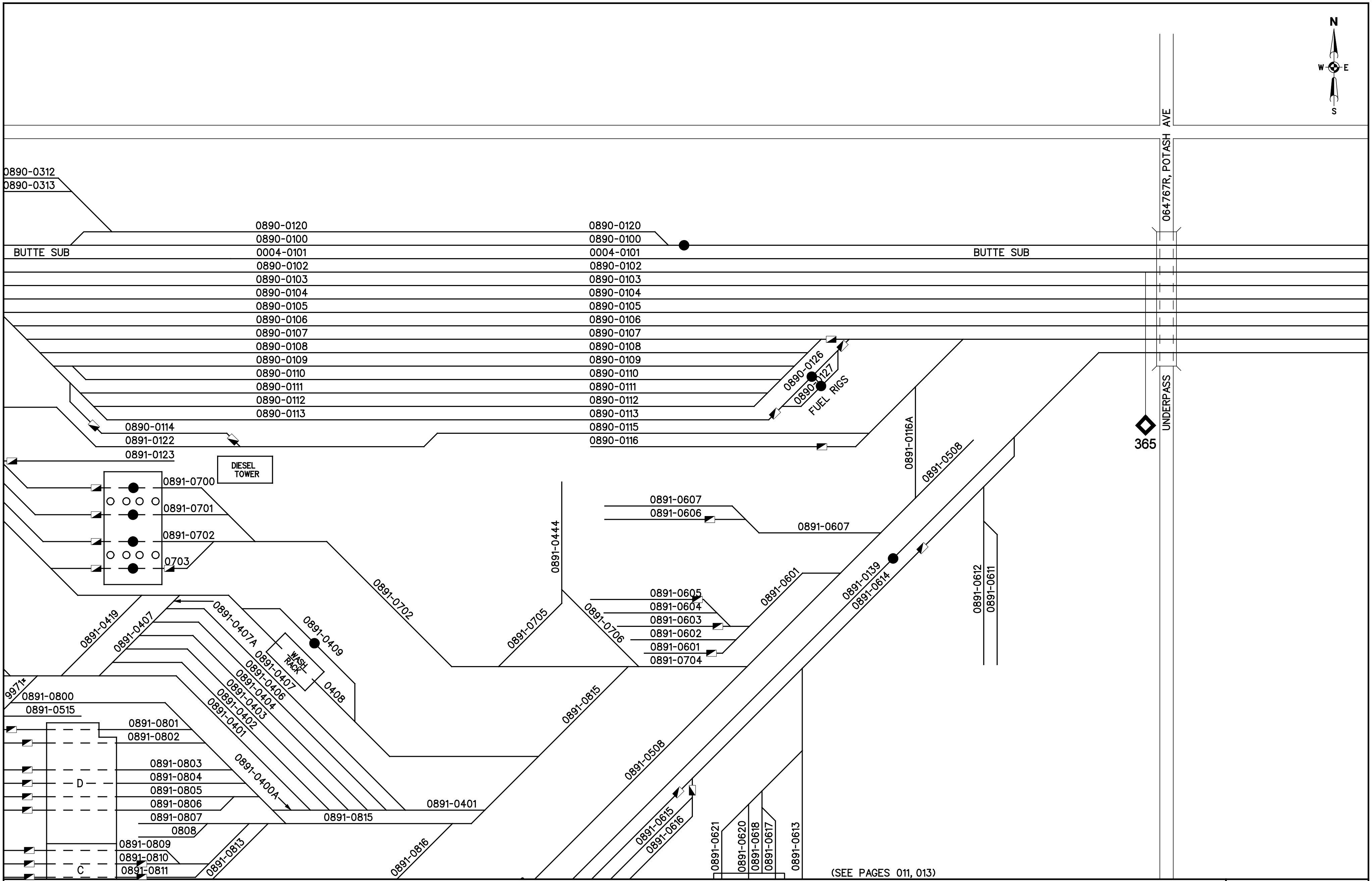
STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/27/2016
TEAM: ALLI01003.DGN
TRK CHT: SAN007.DGN

◄— Edgemont, SD

ALLIANCE, NE - Sand Hills Subdivision

Ravenna, NE —►



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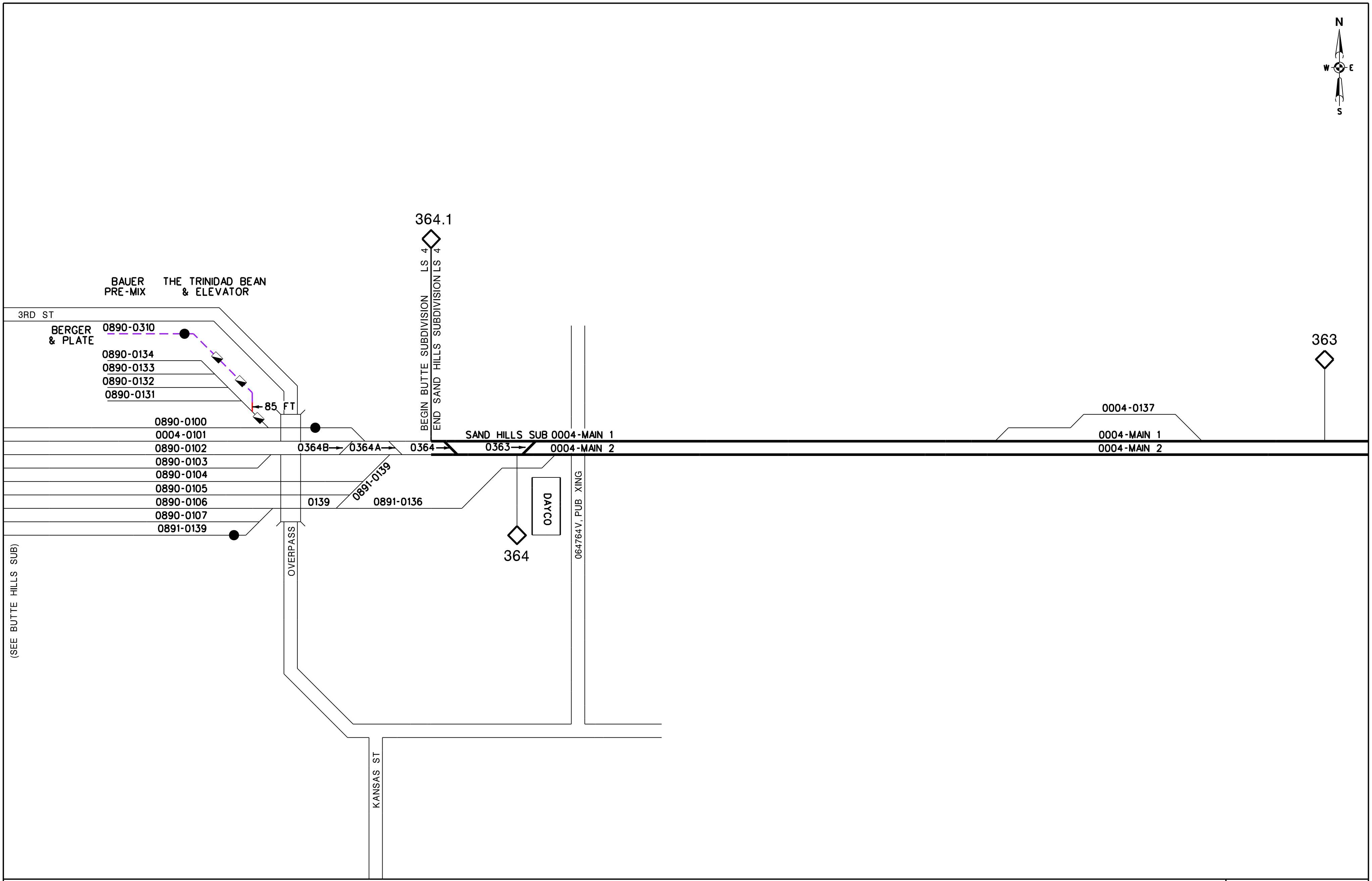
STATION ABBR: ALLINE
FSAC: 30364
REVISED: 12/27/2016
TEAM: ALLI01005.DGN
TRK CHT: SAN008.DGN
TEAM PG 005

← Edgemont, SD

ALLIANCE, NE
Sand Hills Subdivision

Ravenna, NE →



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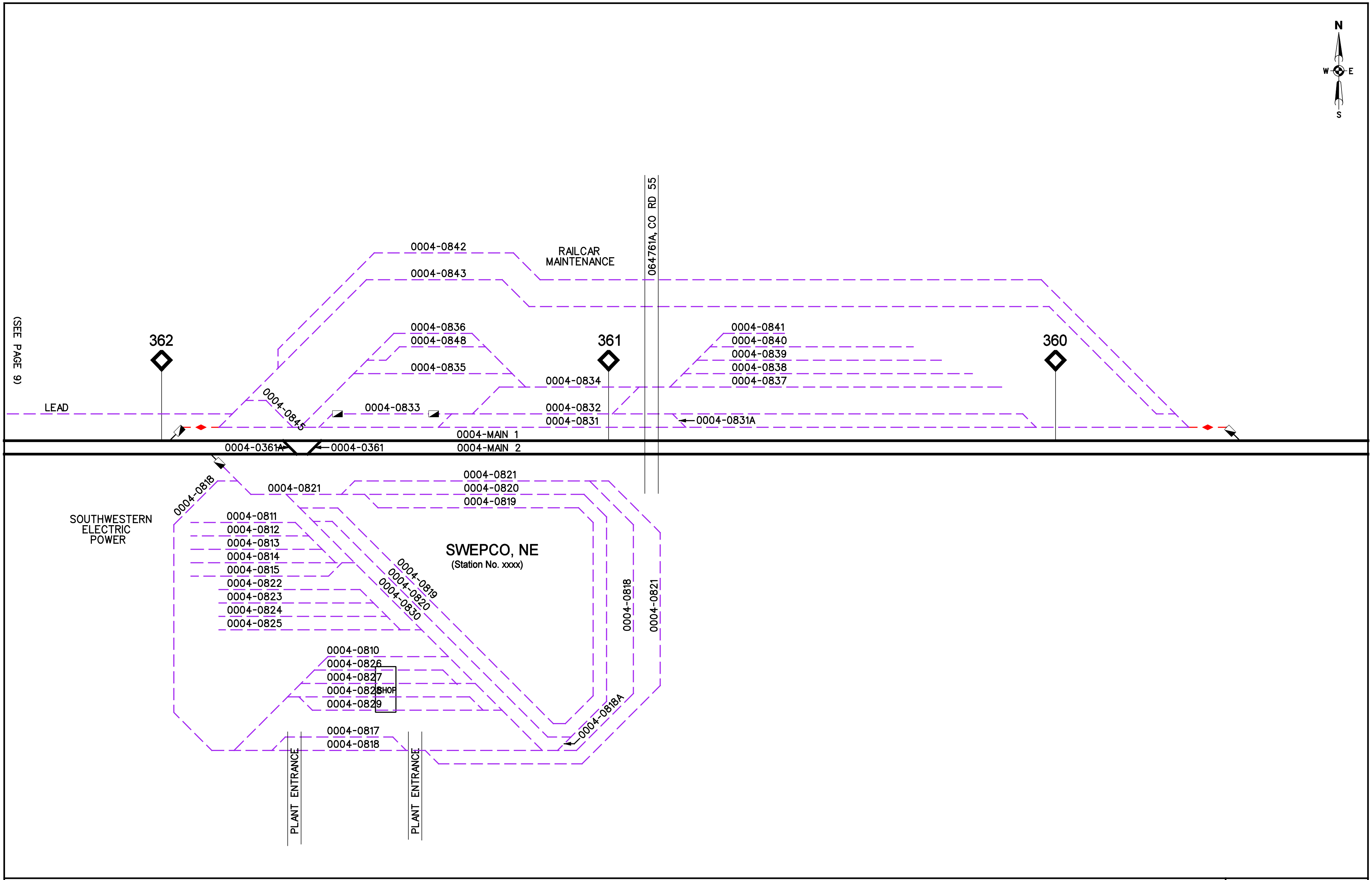
STATION ABBR: ALLINE
FSAC: 30364
REVISED: 11/7/2017
TEAM: ALLI01009.DGN
TRK CHT: SAN009.DGN

KOESTER, NE
Sand Hills Subdivision

← East Alliance, NE

Ravenna, NE →



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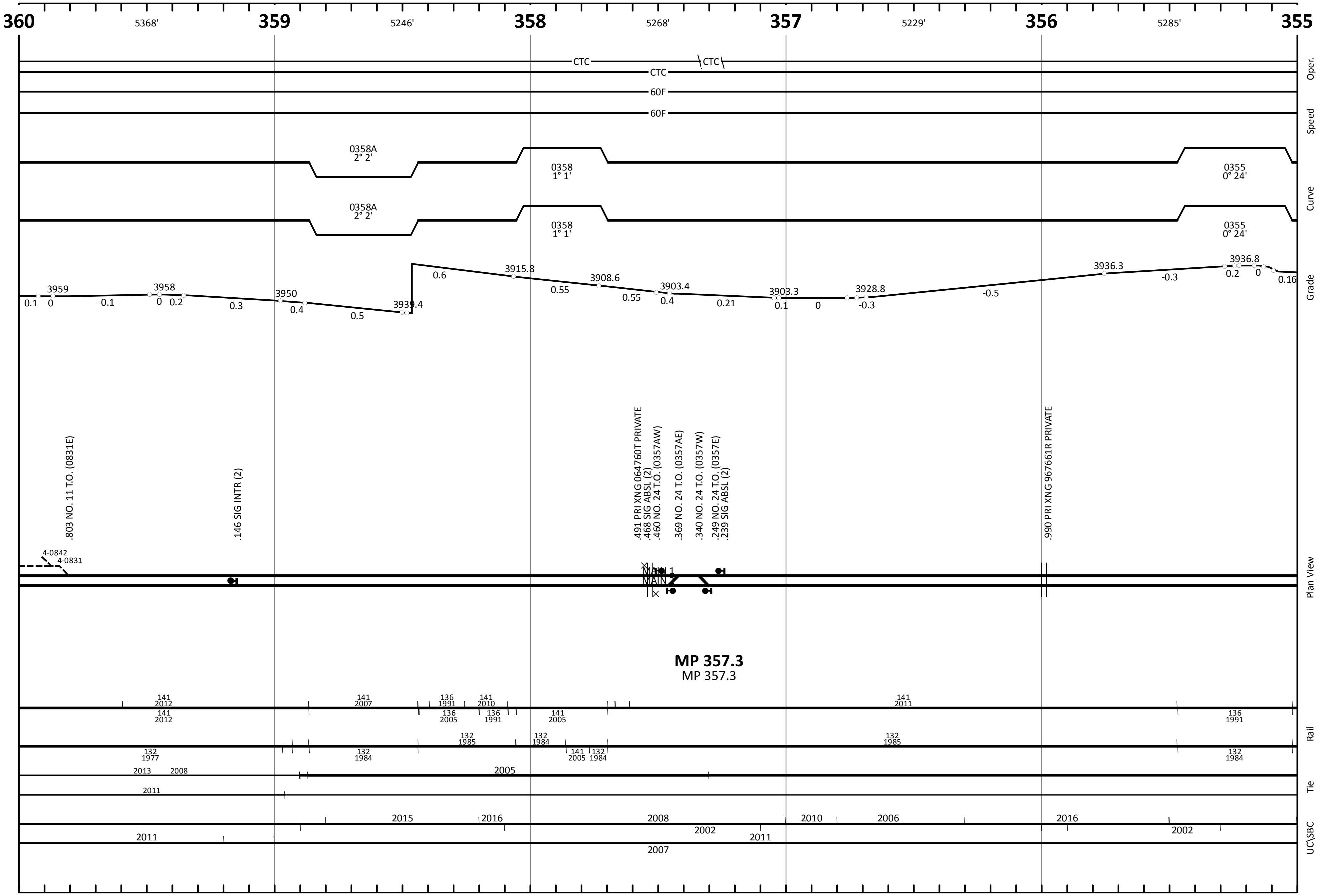
◪	DERAIL
—+—+—	JOINT FACILITIES
▬▬	TRACKAGE RIGHTS
—+—+—	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: KSTRNE
FSAC: 30364
REVISED: 11/7/2014
TEAM: KOES08015.DGN
TRK CHT: SAN010.DGN

◄ (WB) EAST ALLIANCE, NE Line Segment 4 RAVENNA, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

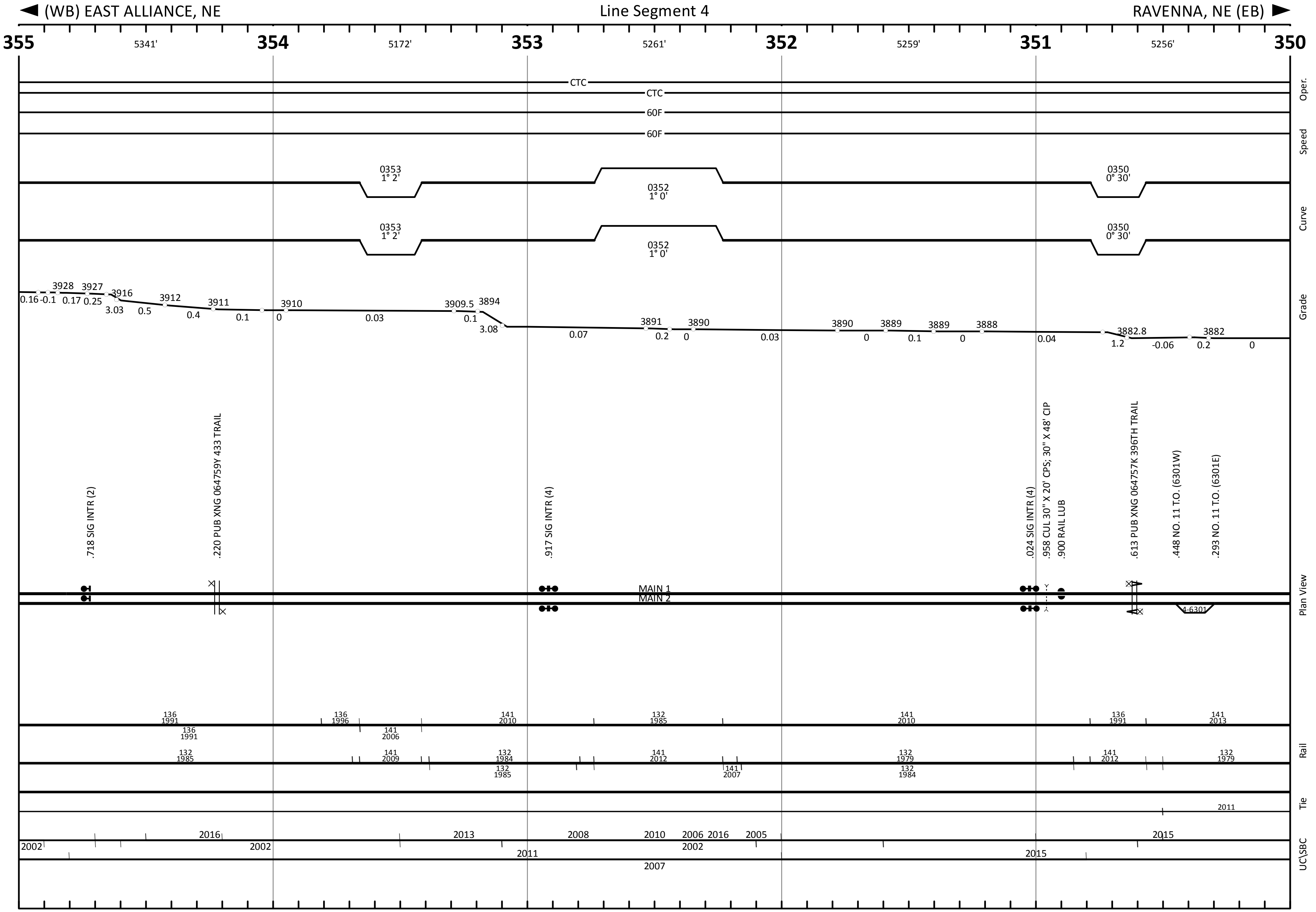
Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018



BNSF RAILWAY

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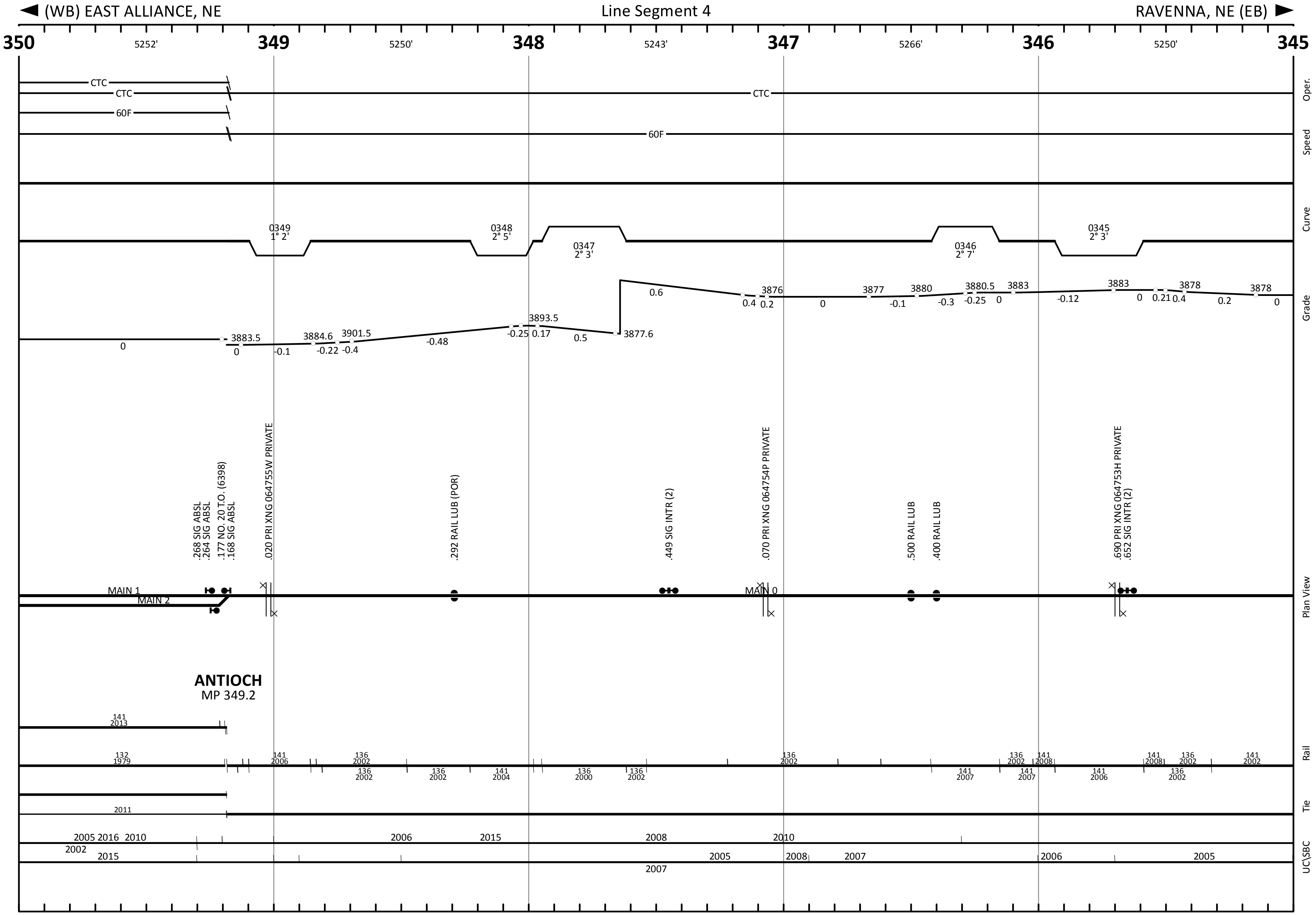

BNSF RAILWAY

System Maintenance and Planning

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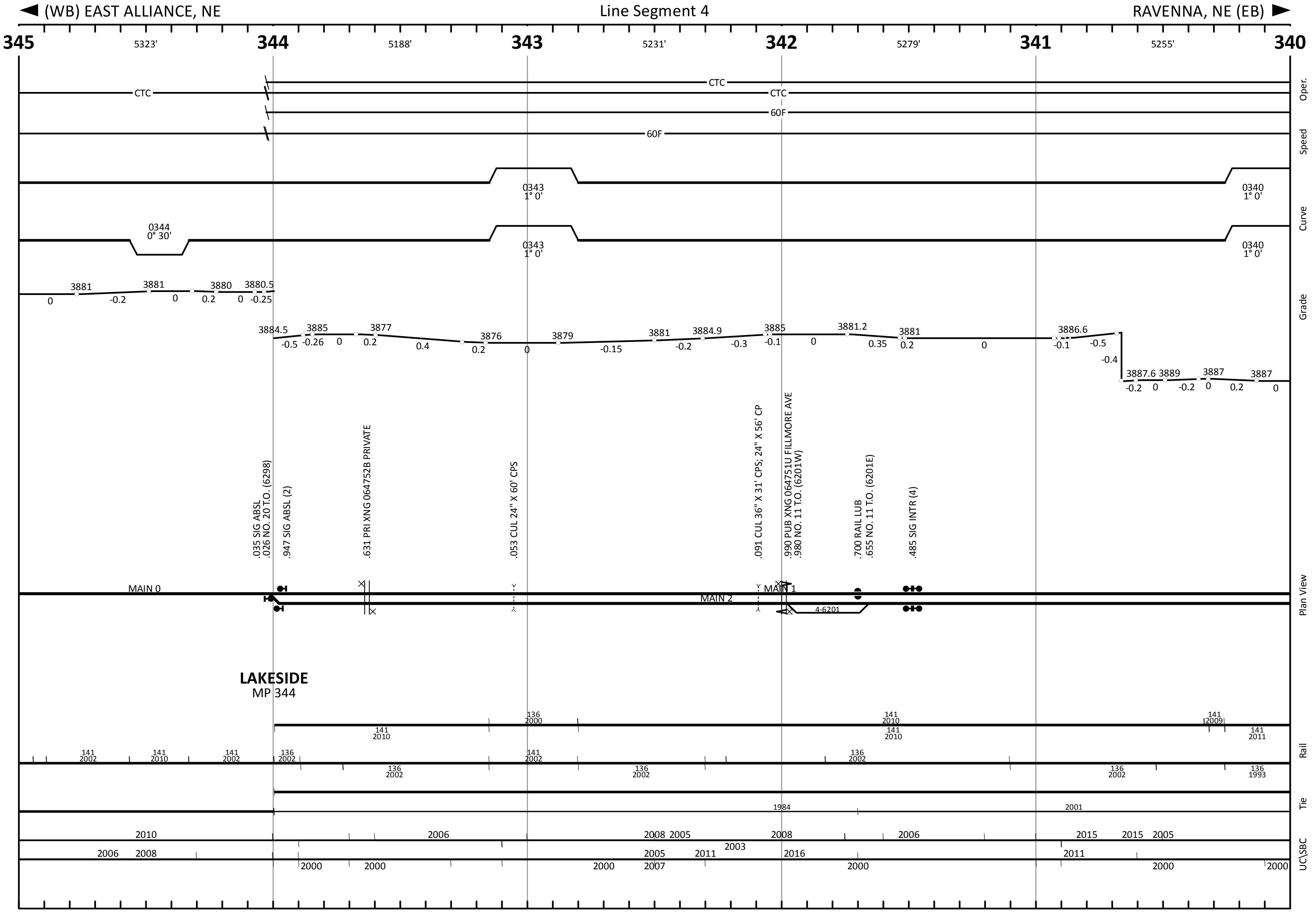

Sand Hills Subdivision

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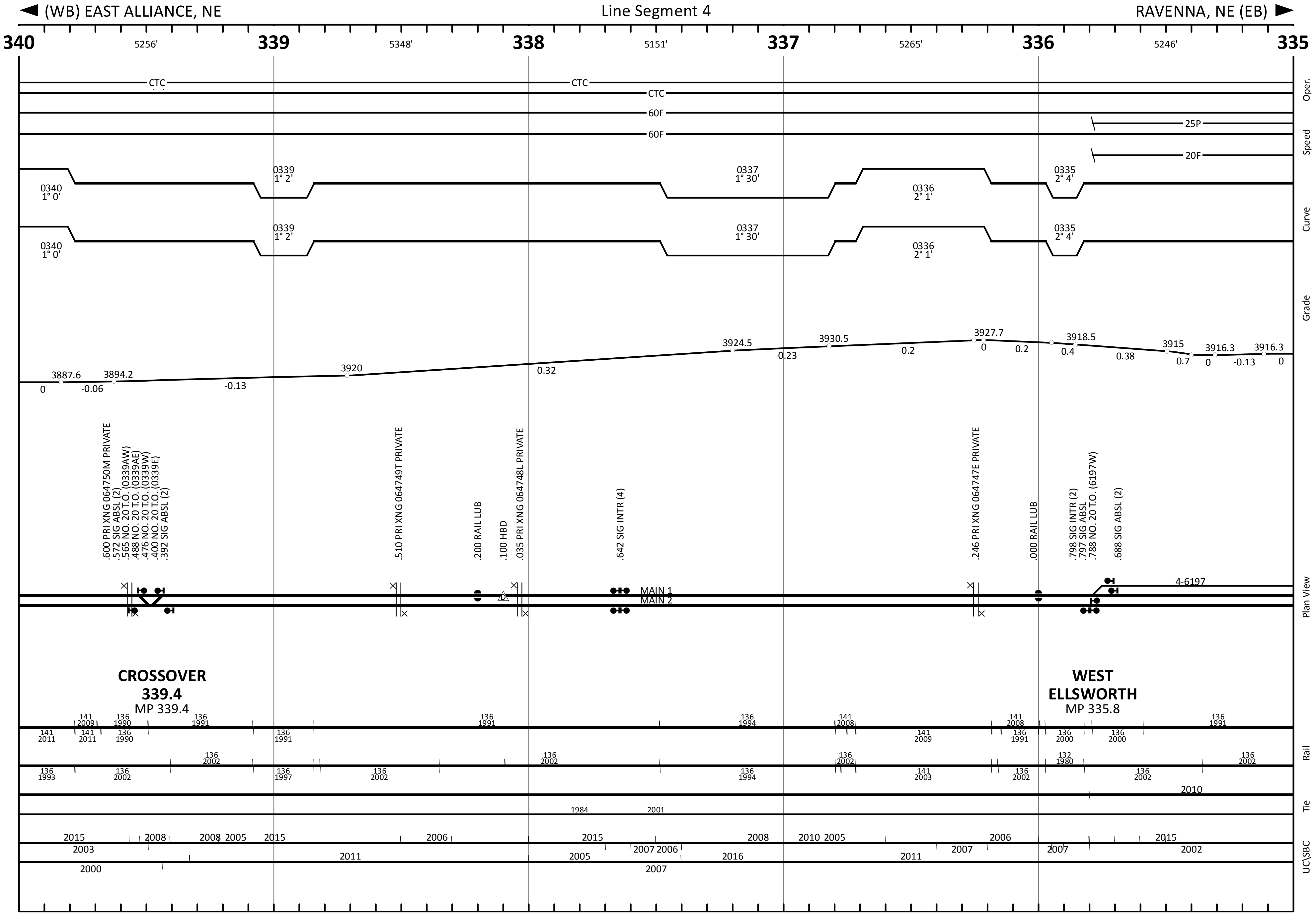

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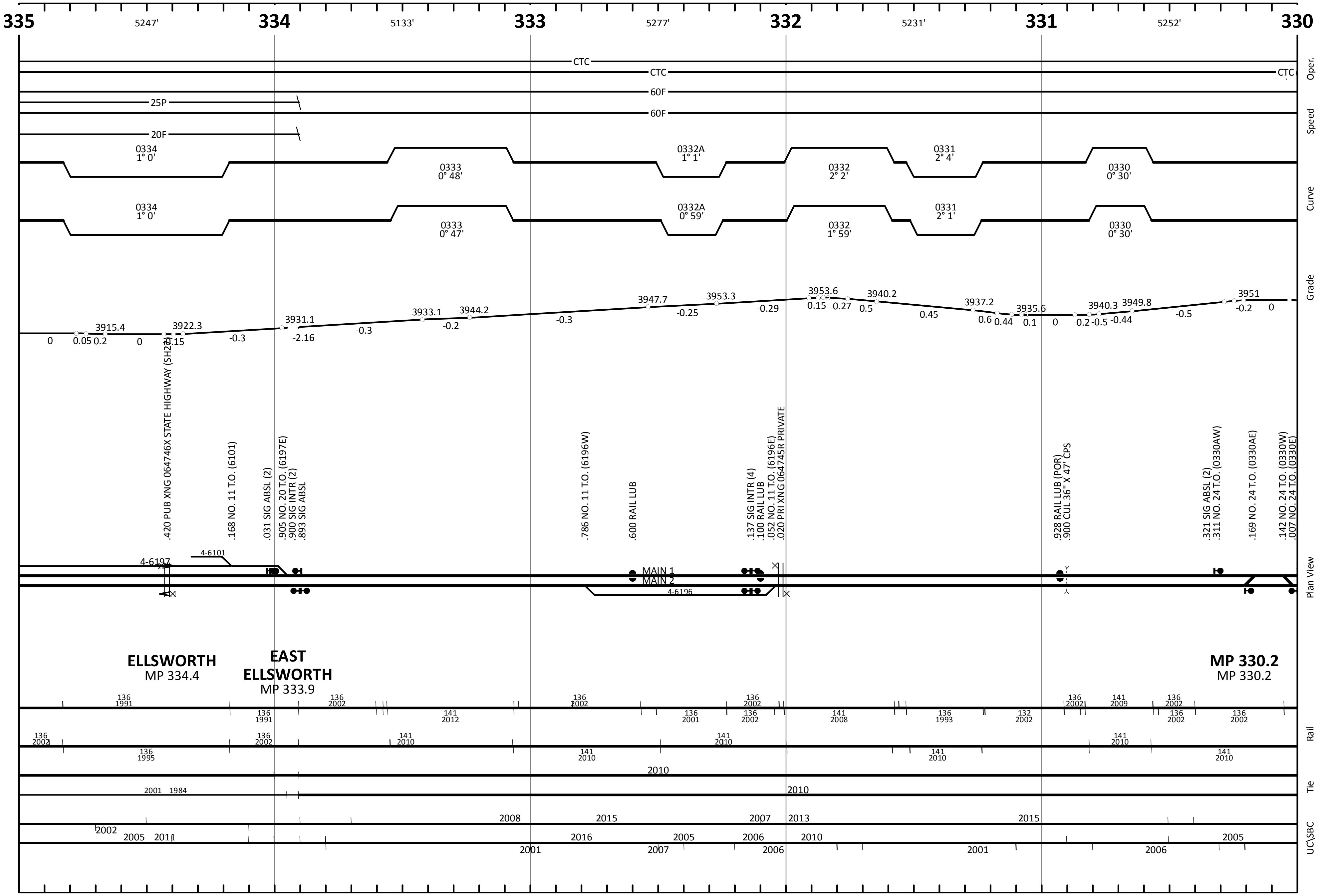

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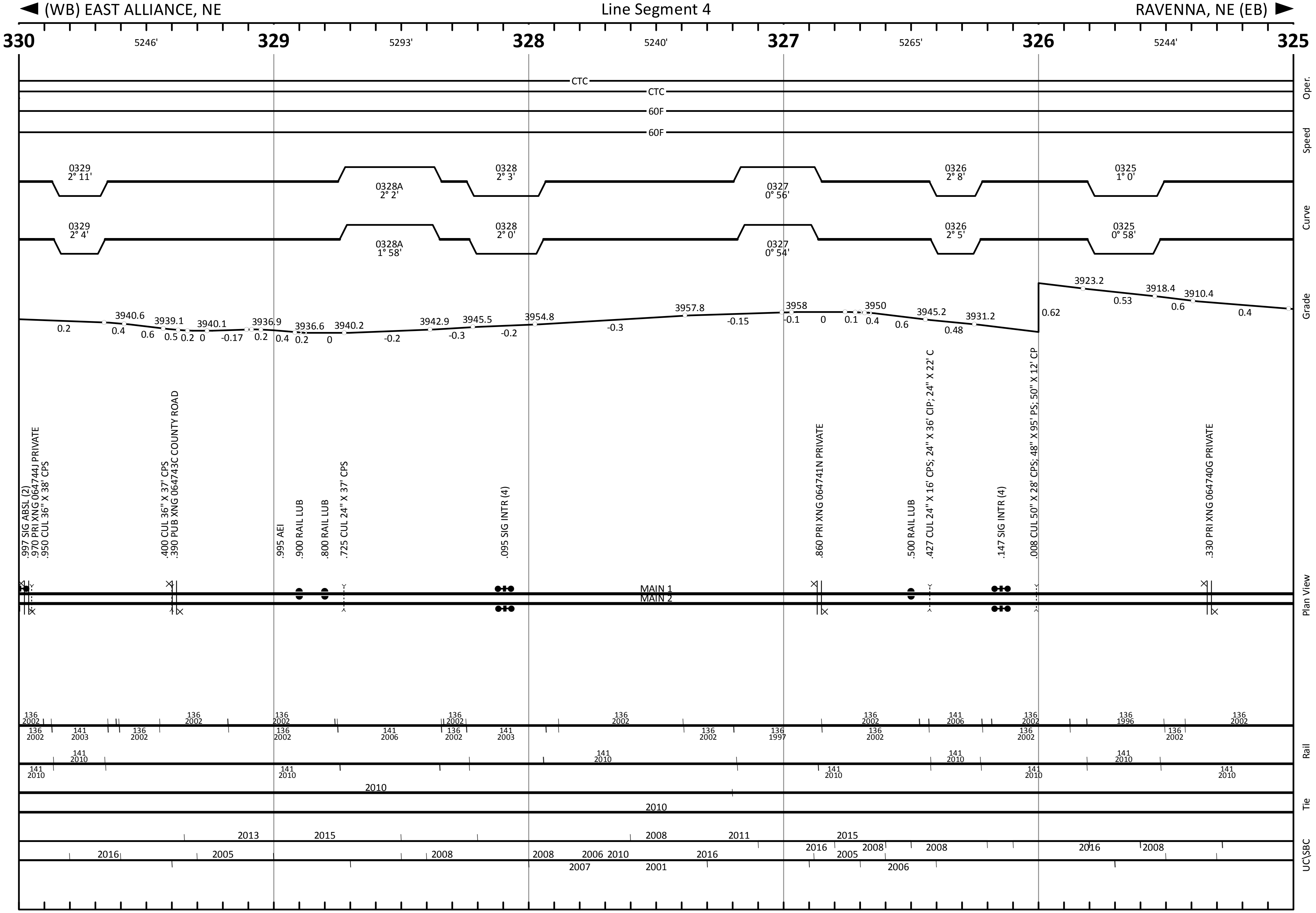

System Maintenance and Planning

Sand Hills Subdivision

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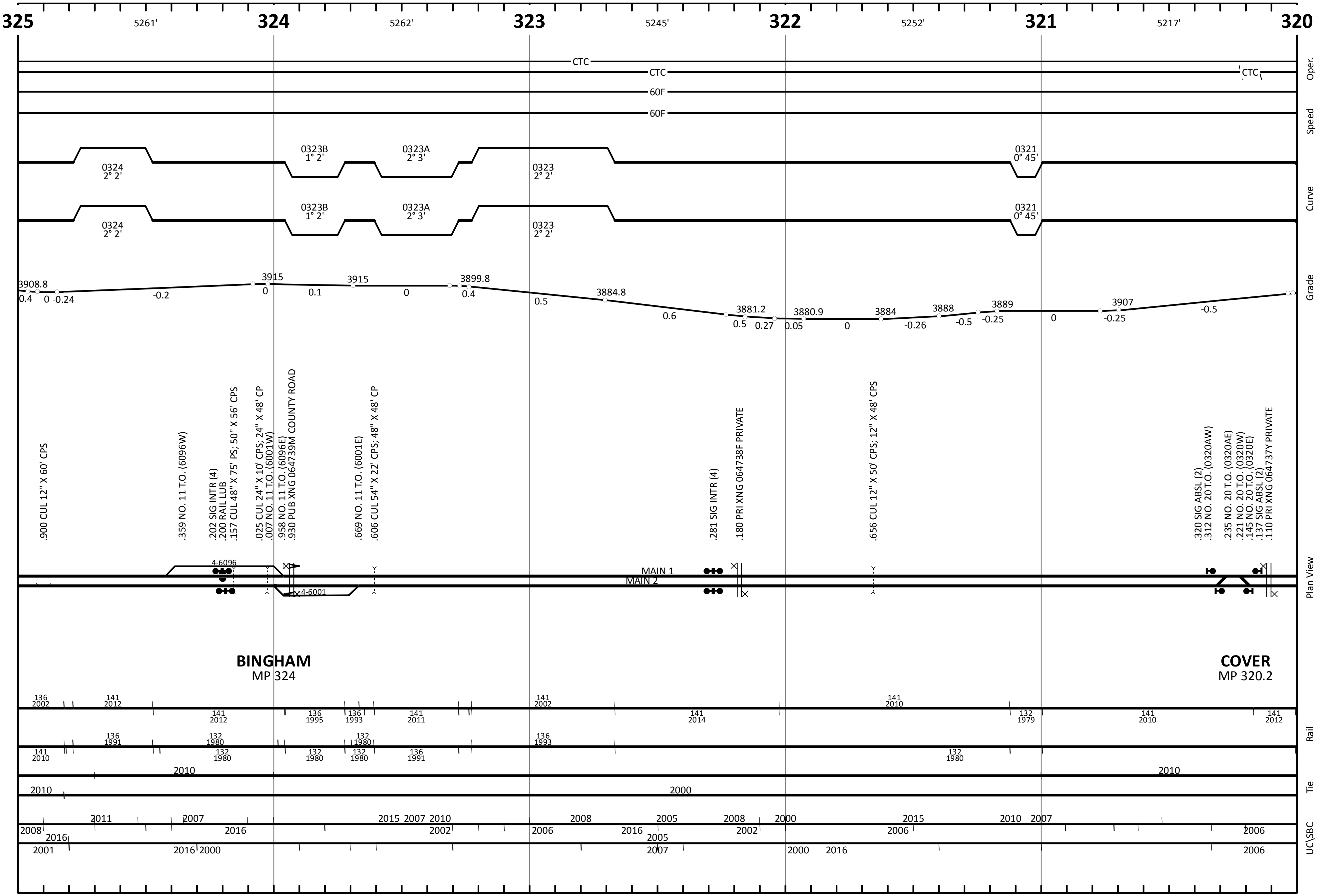
Revised to July 16, 2018 Page 17 of 61

◄ (WB) EAST ALLIANCE, NE   Line Segment 4   RAVENNA, NE (EB) ►



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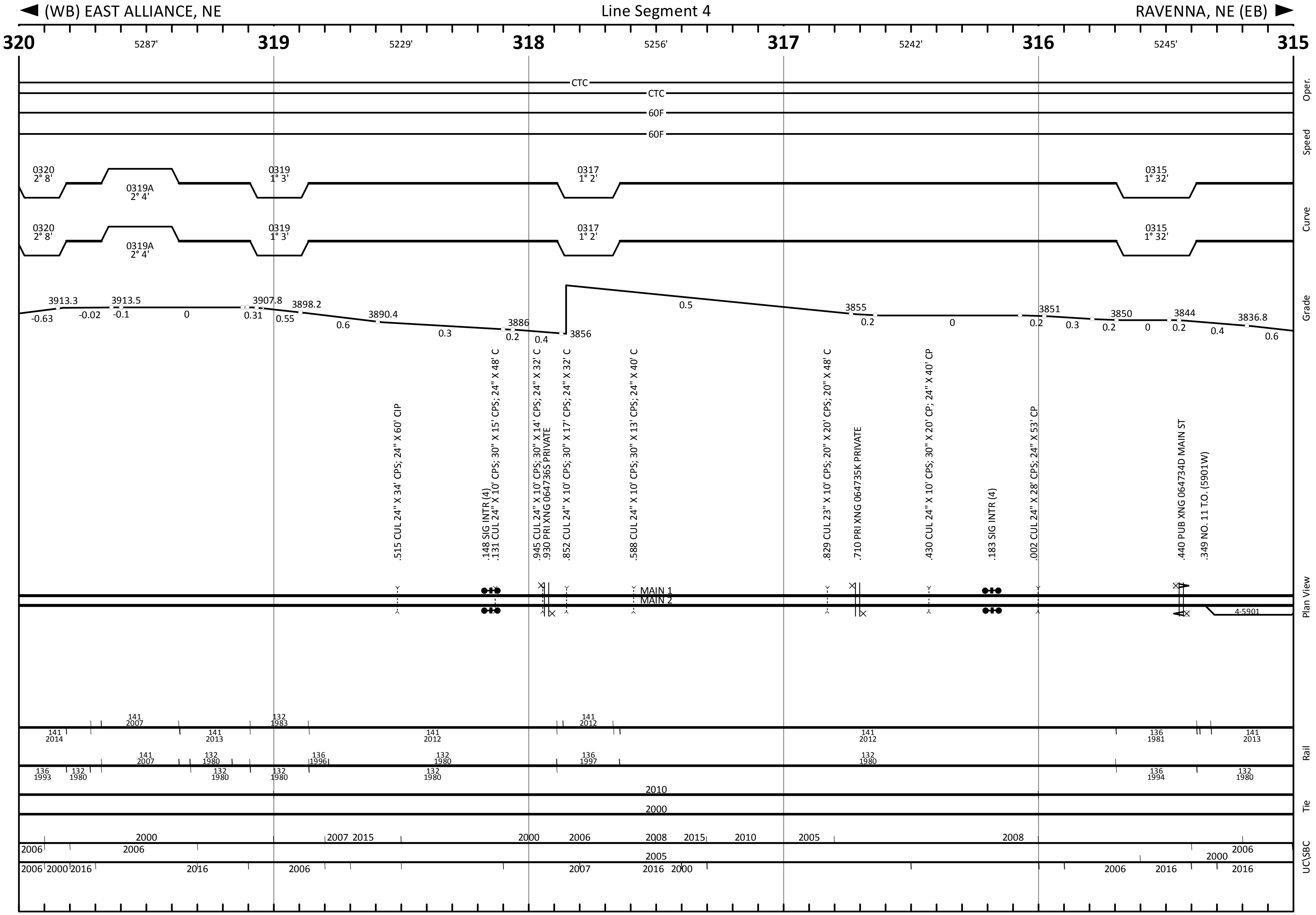

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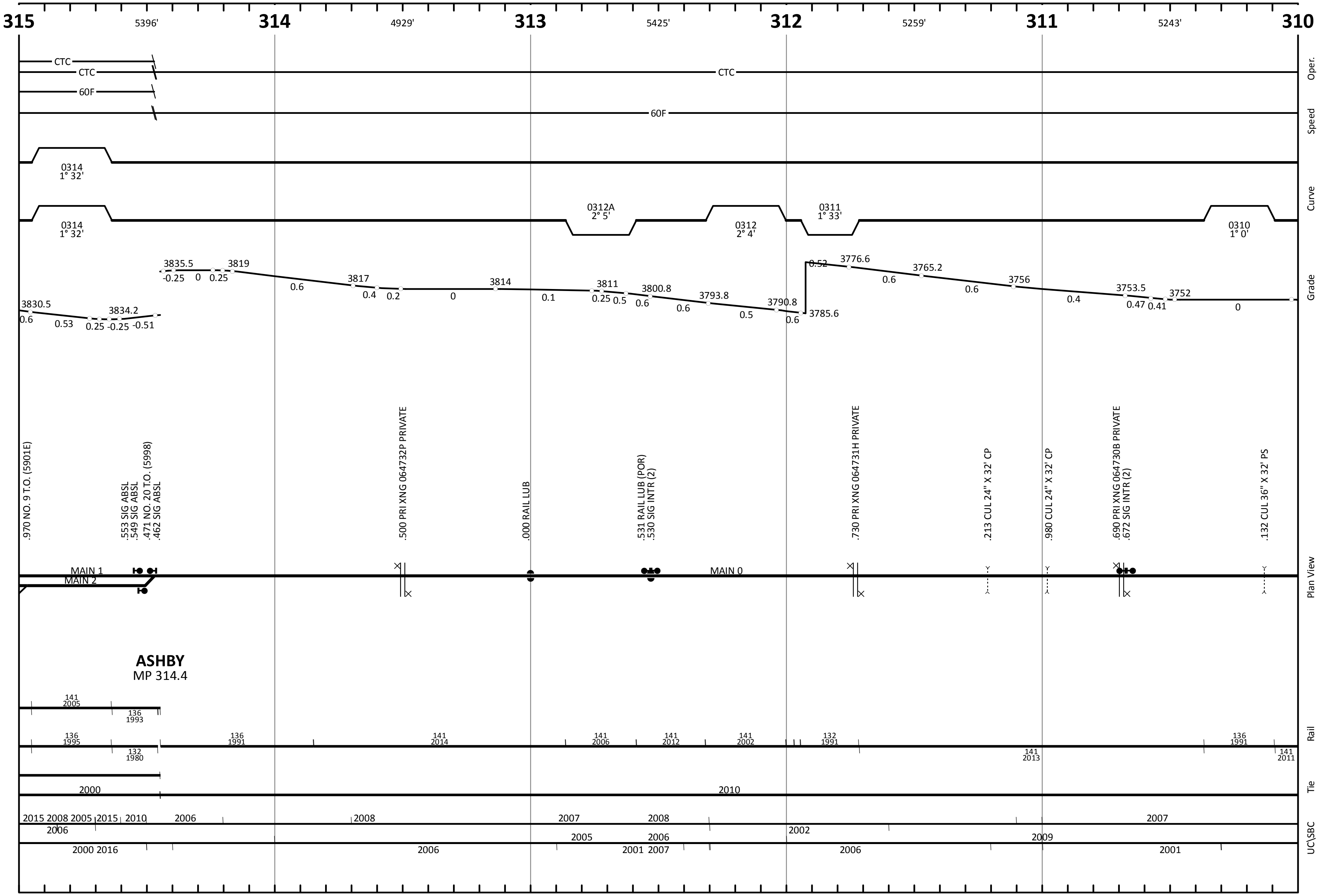

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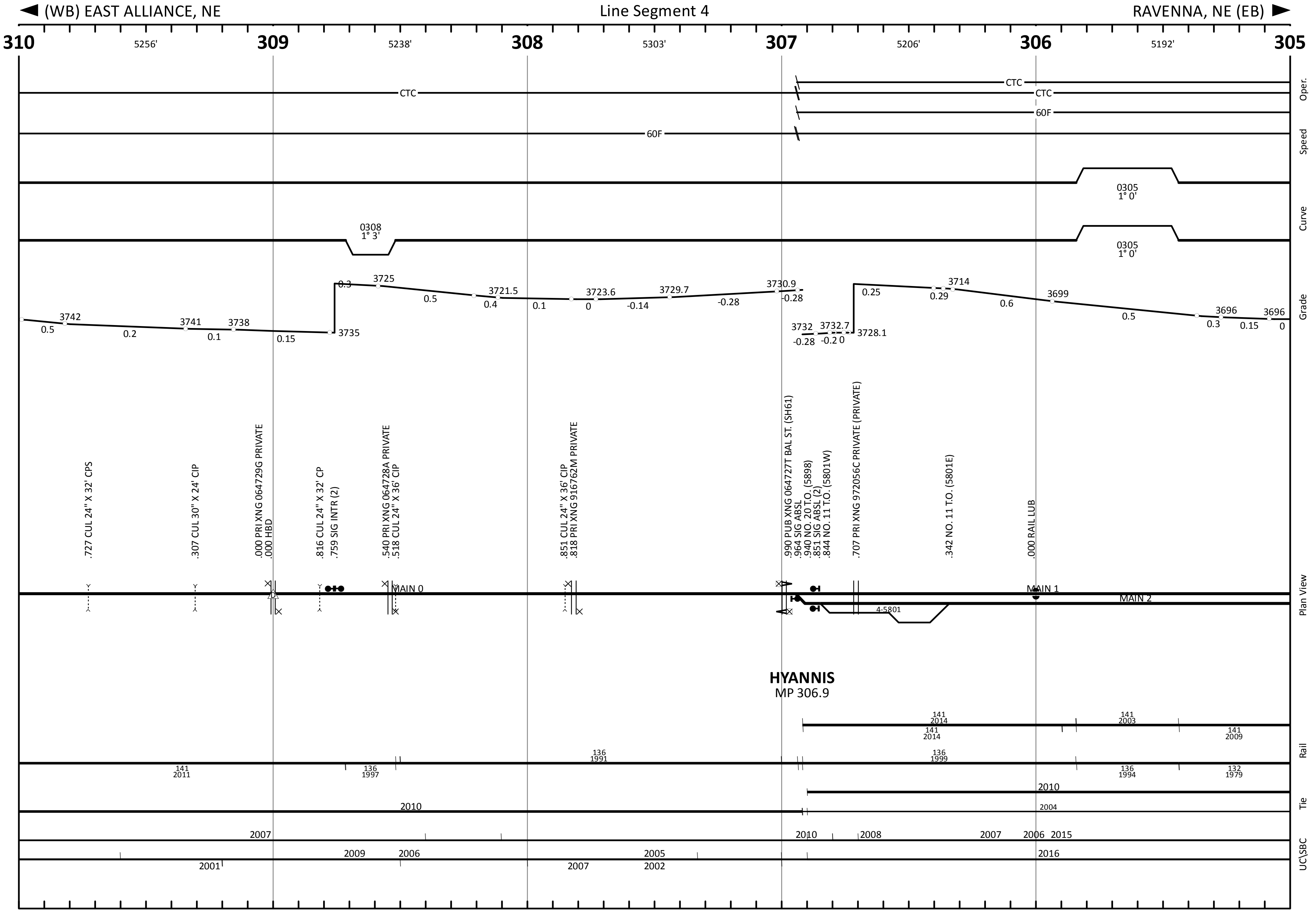

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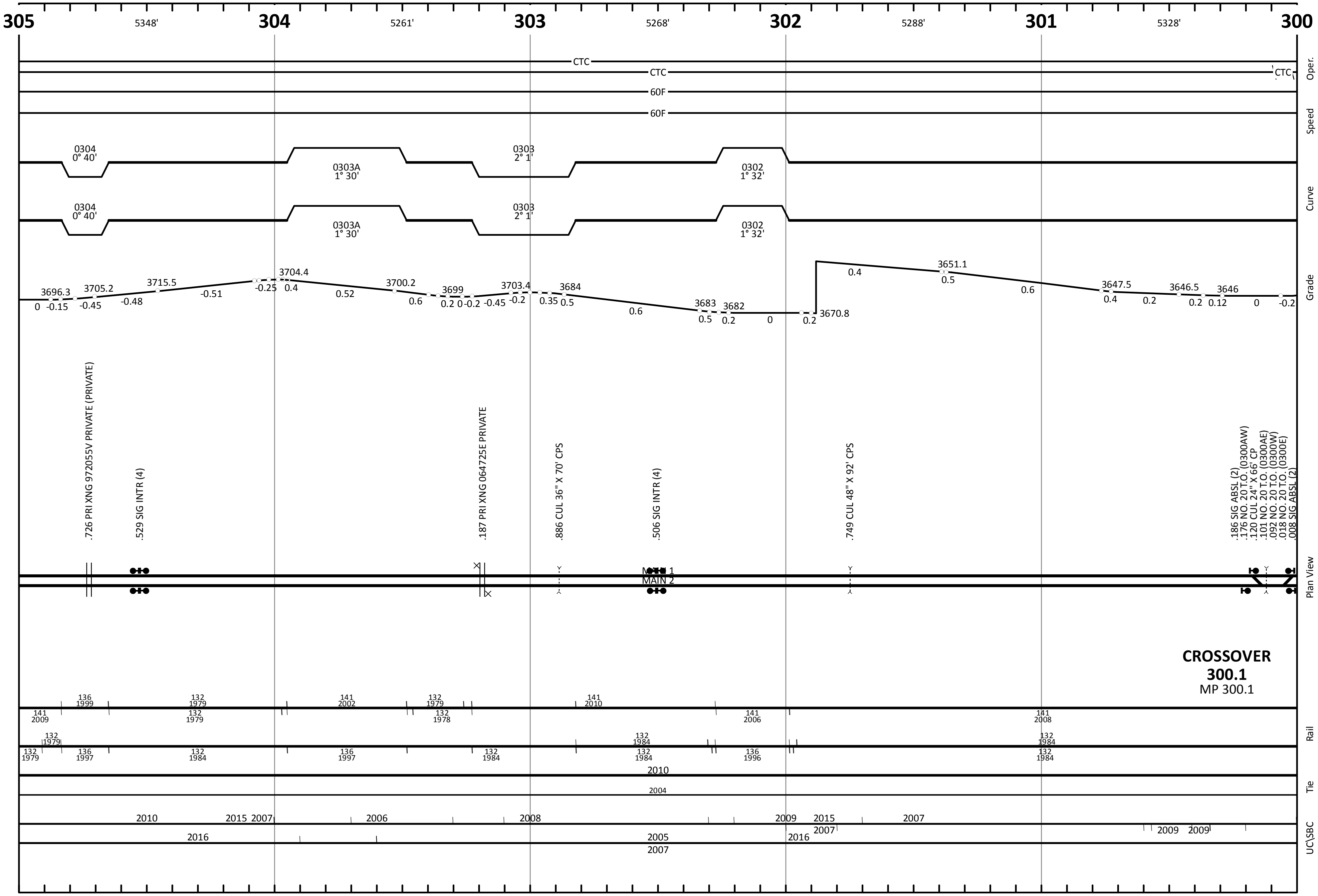

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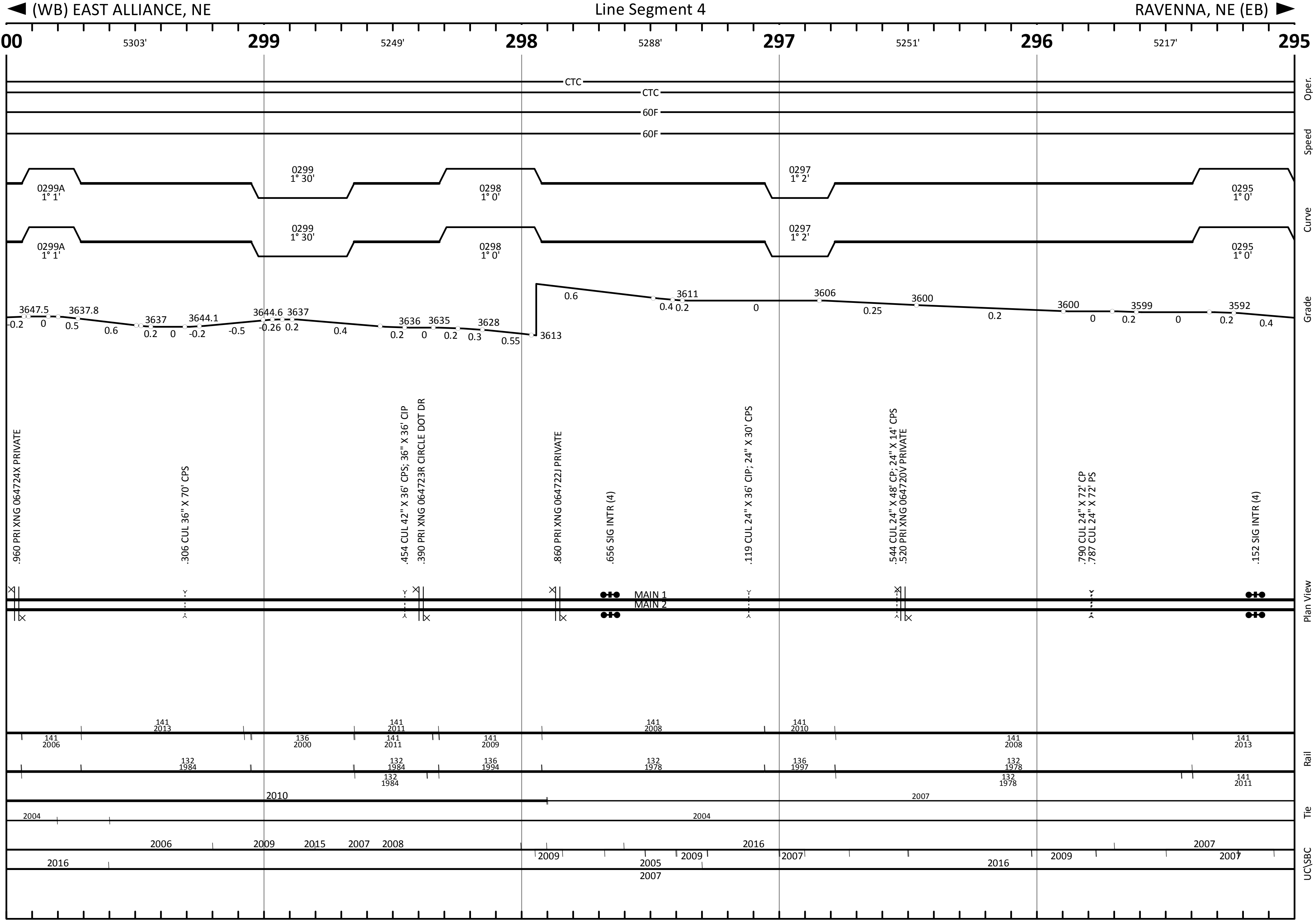

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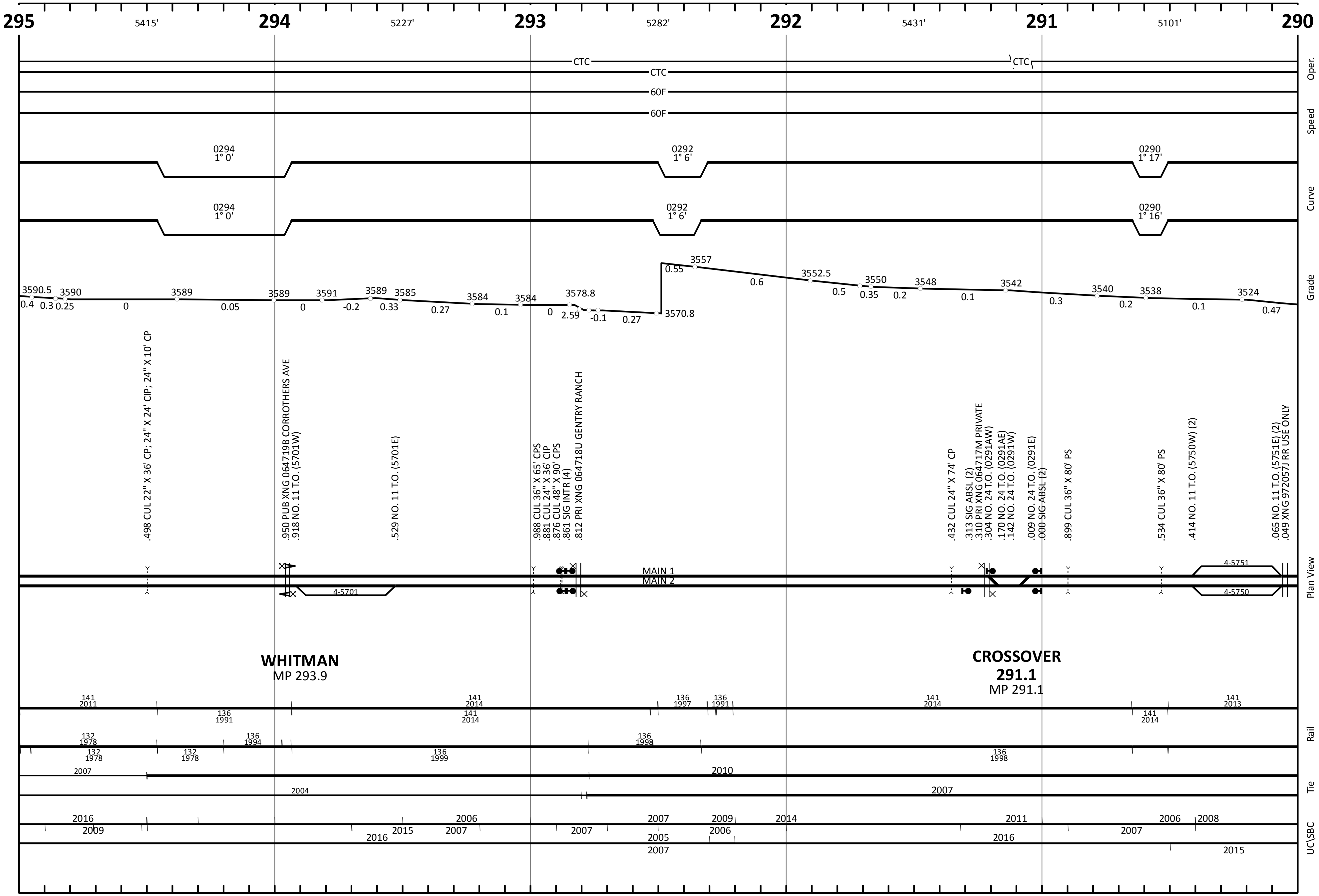

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System Maintenance and Planning

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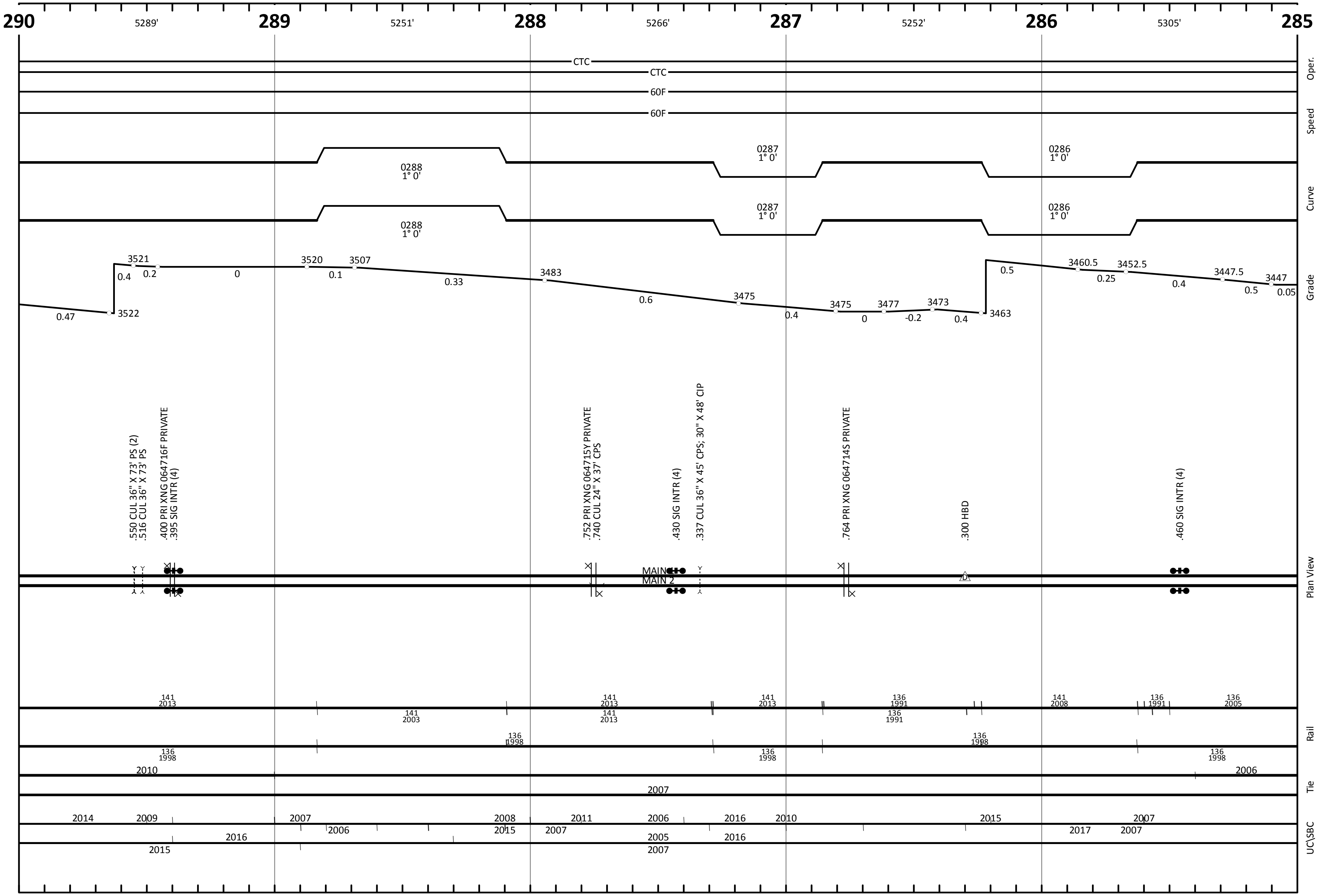
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 16, 2018 Page 24 of 61

◄ (WB) EAST ALLIANCE, NE   Line Segment 4   RAVENNA, NE (EB) ►



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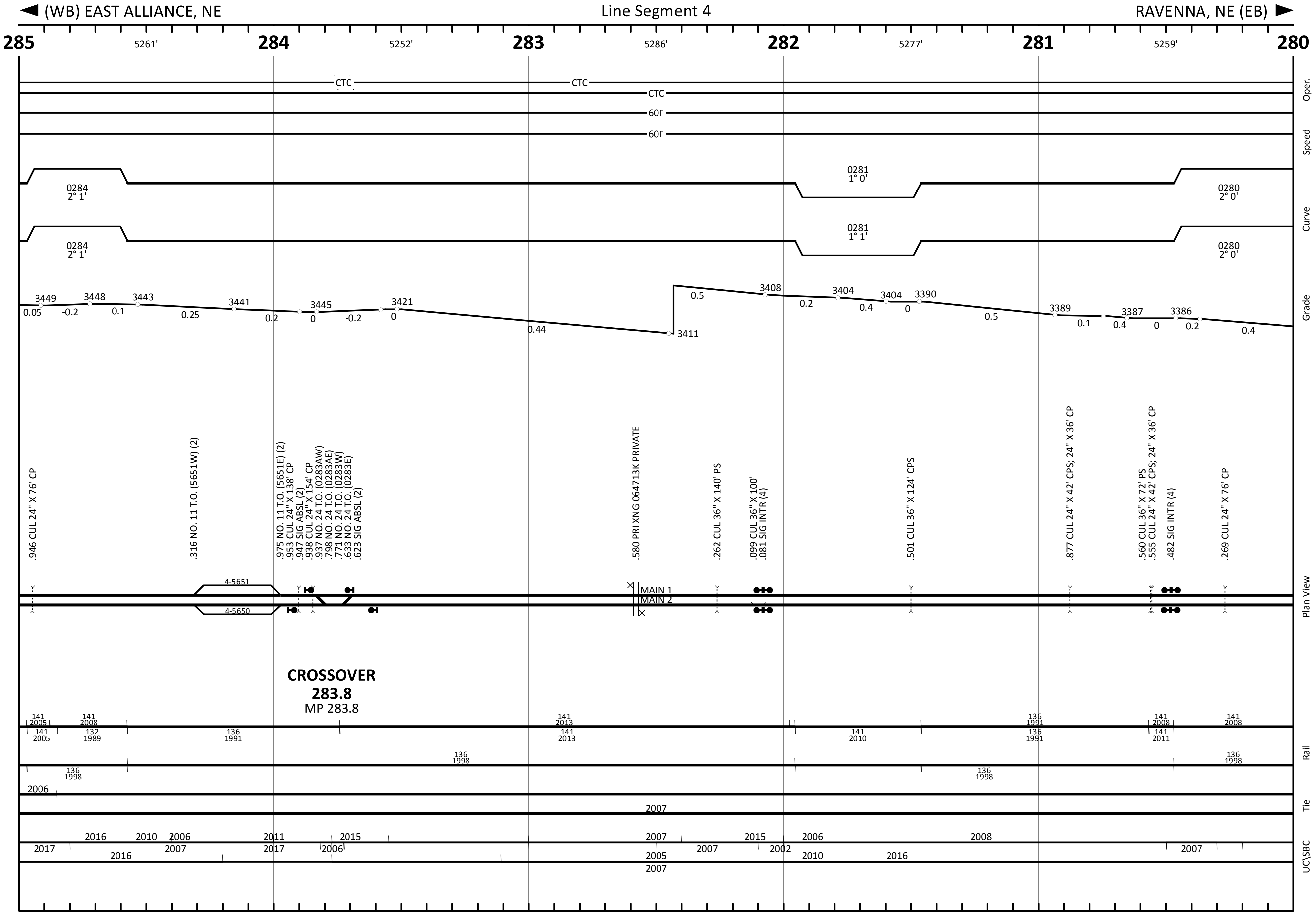

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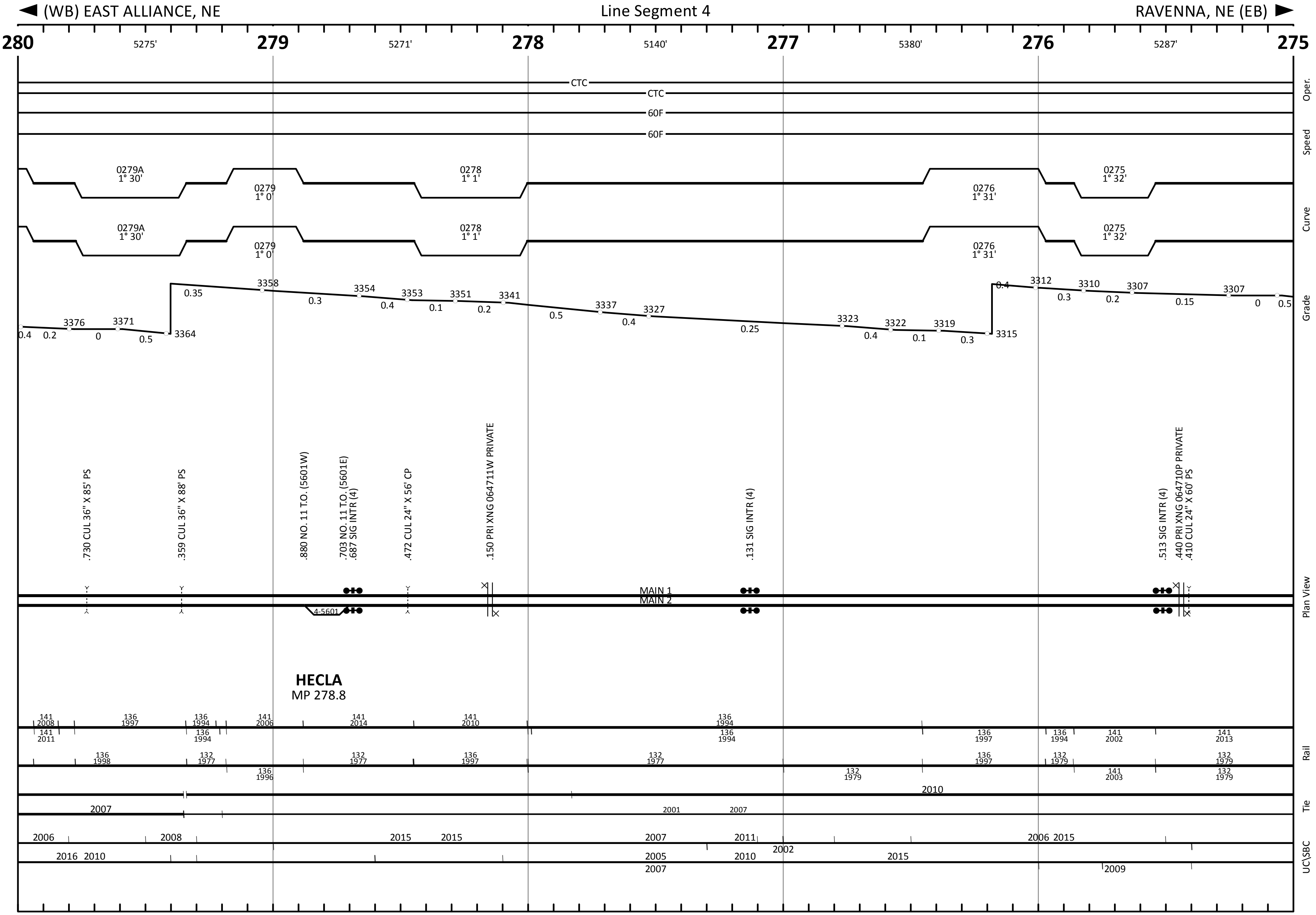

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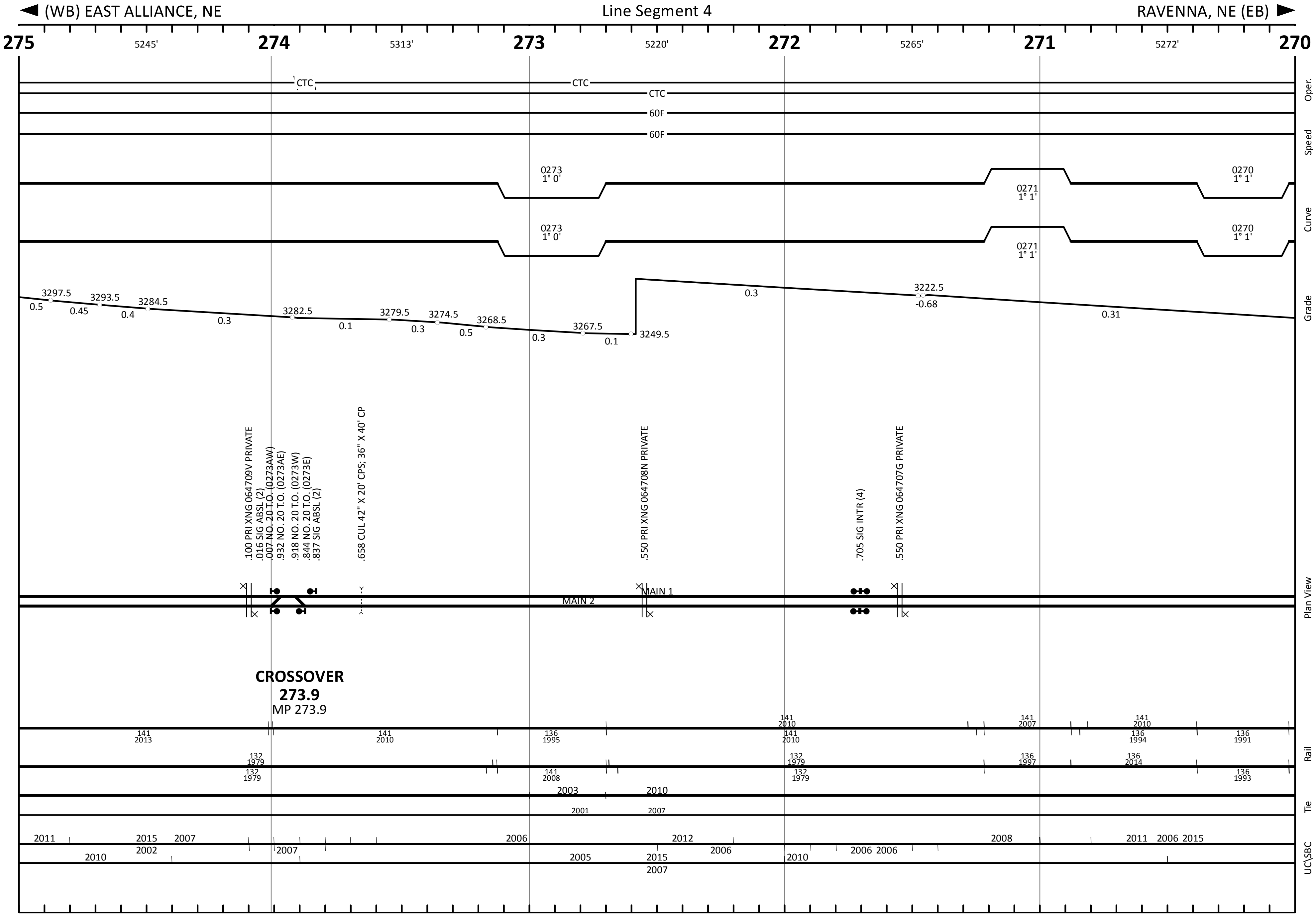

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Revised to July 16, 2018

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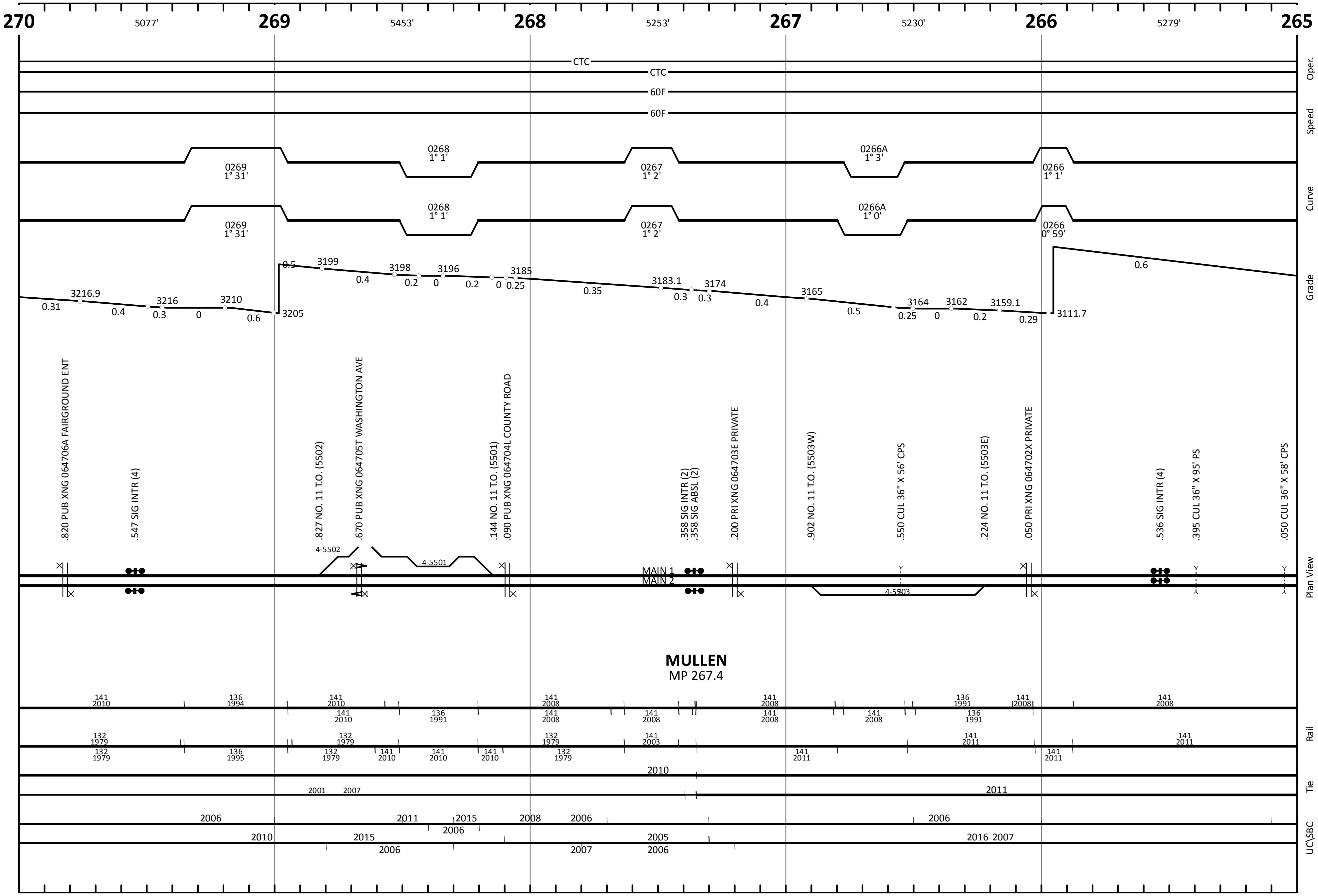

System Maintenance and Planning

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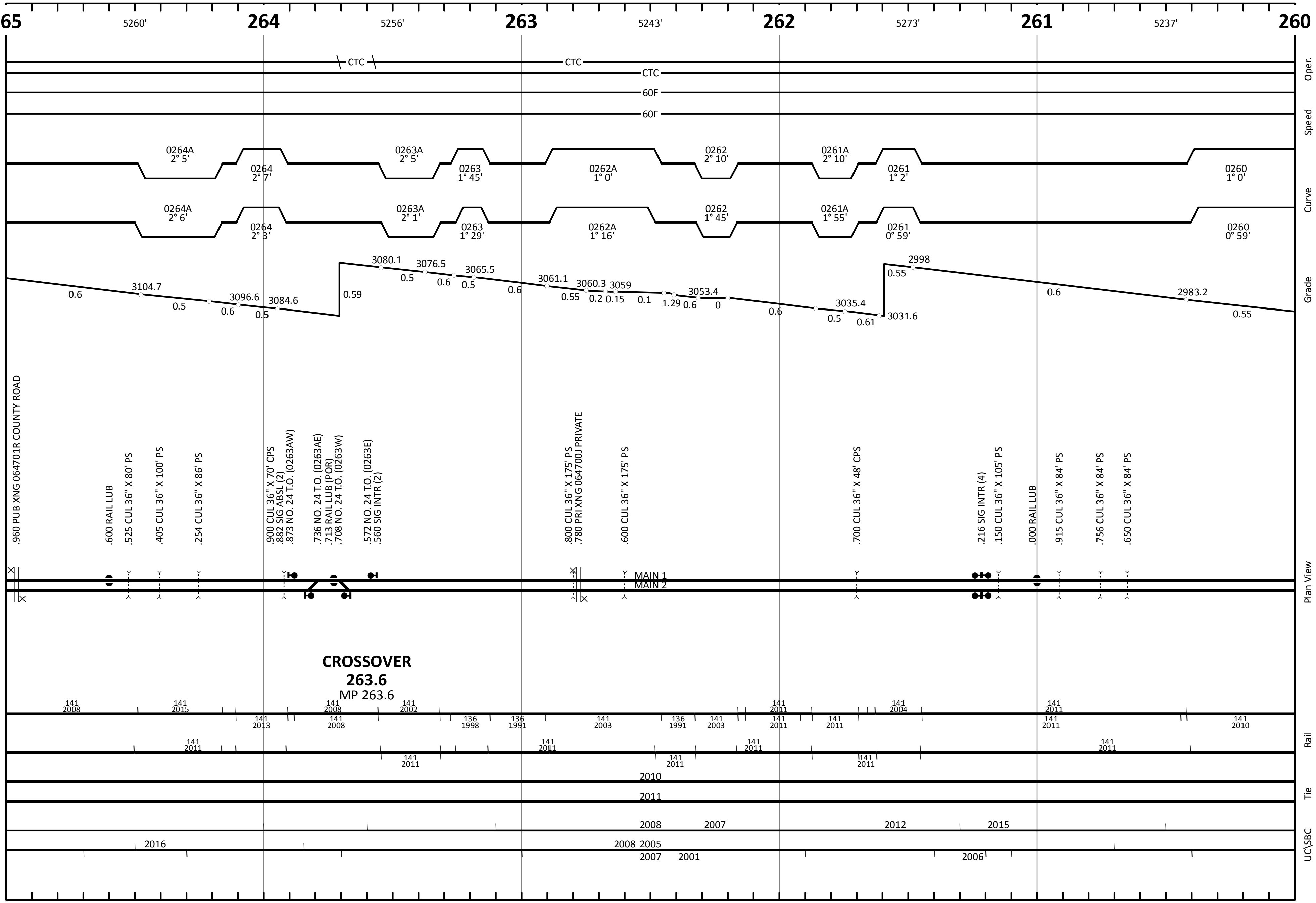

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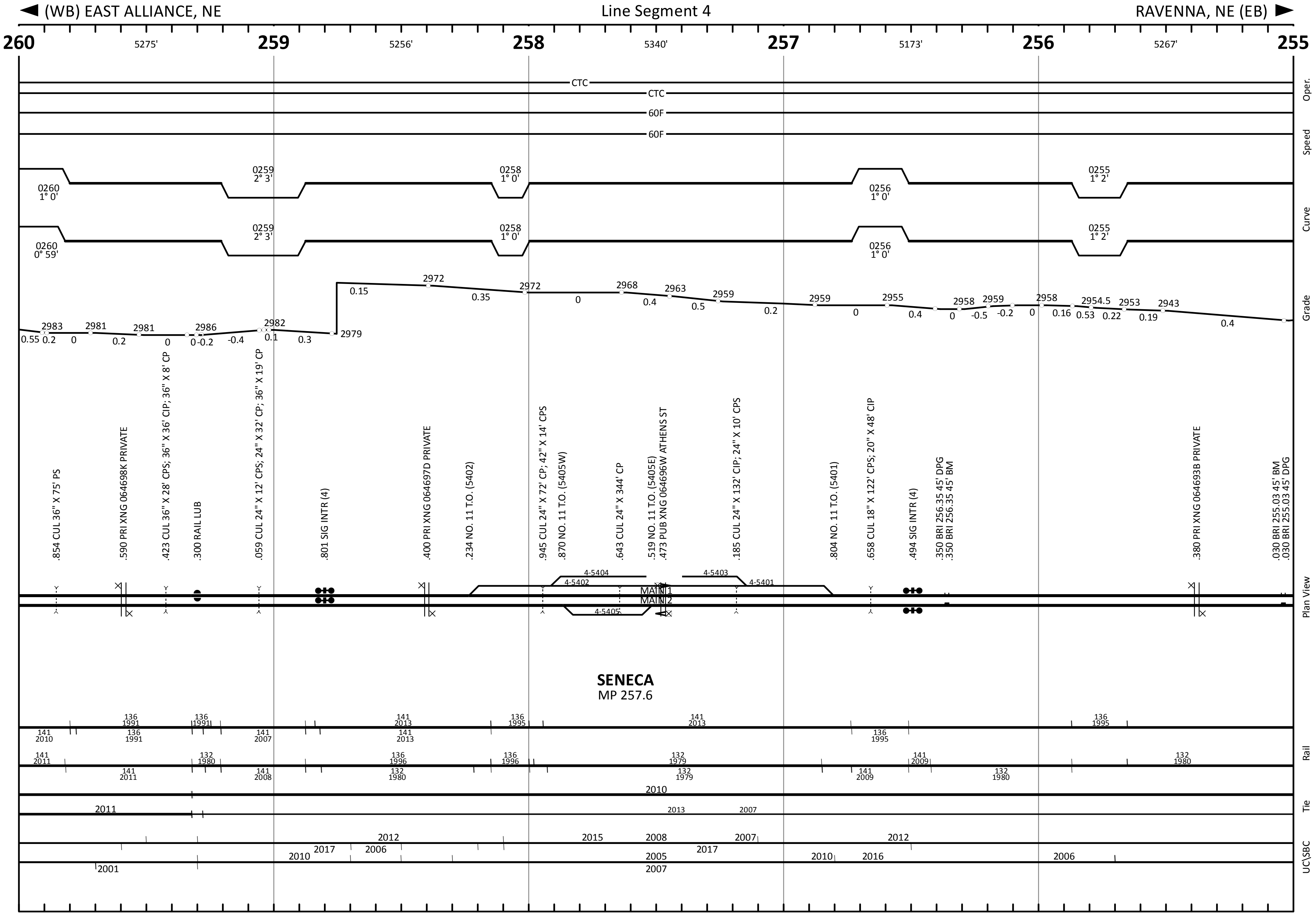

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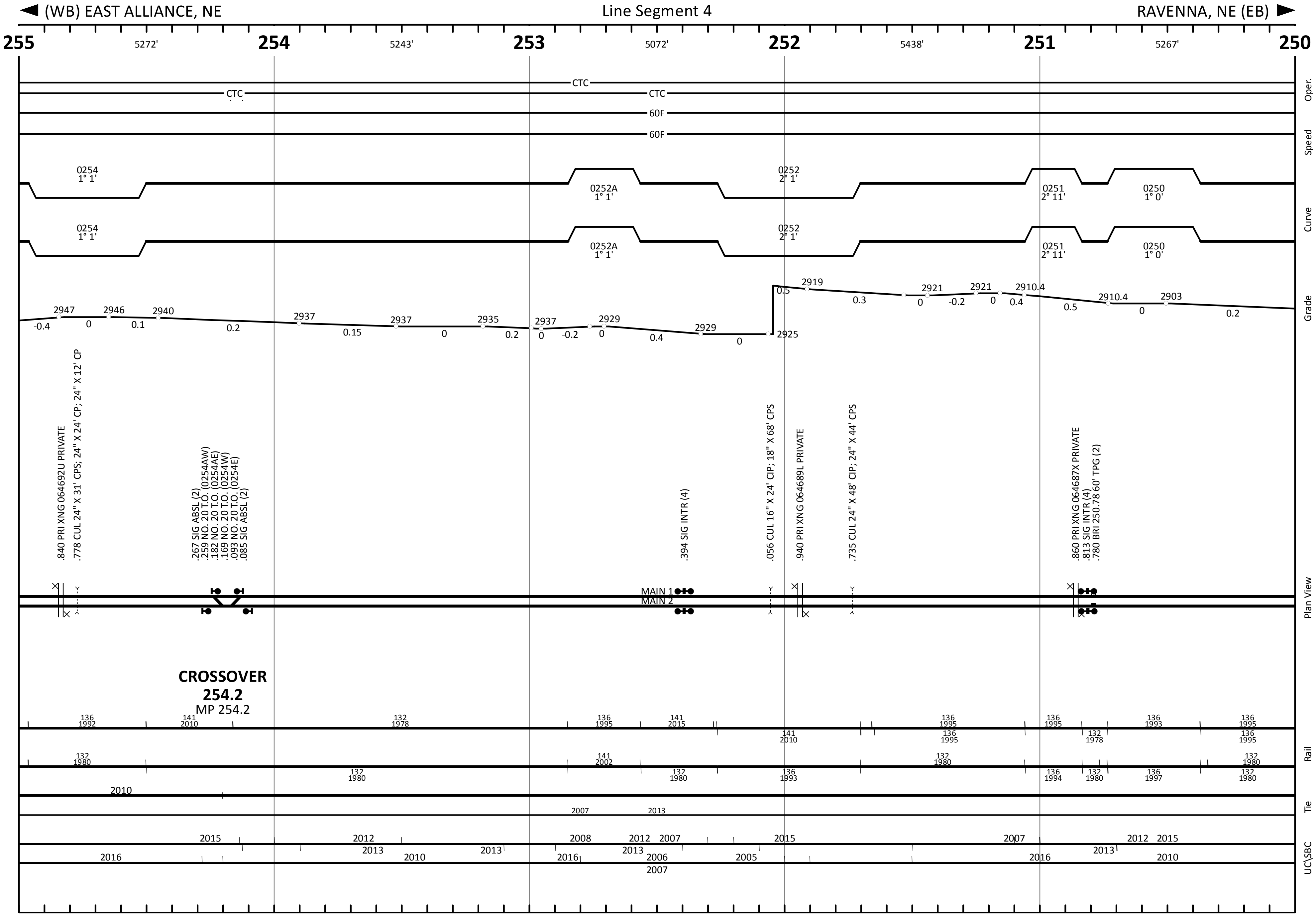

BNSF RAILWAY
System Maintenance and Planning

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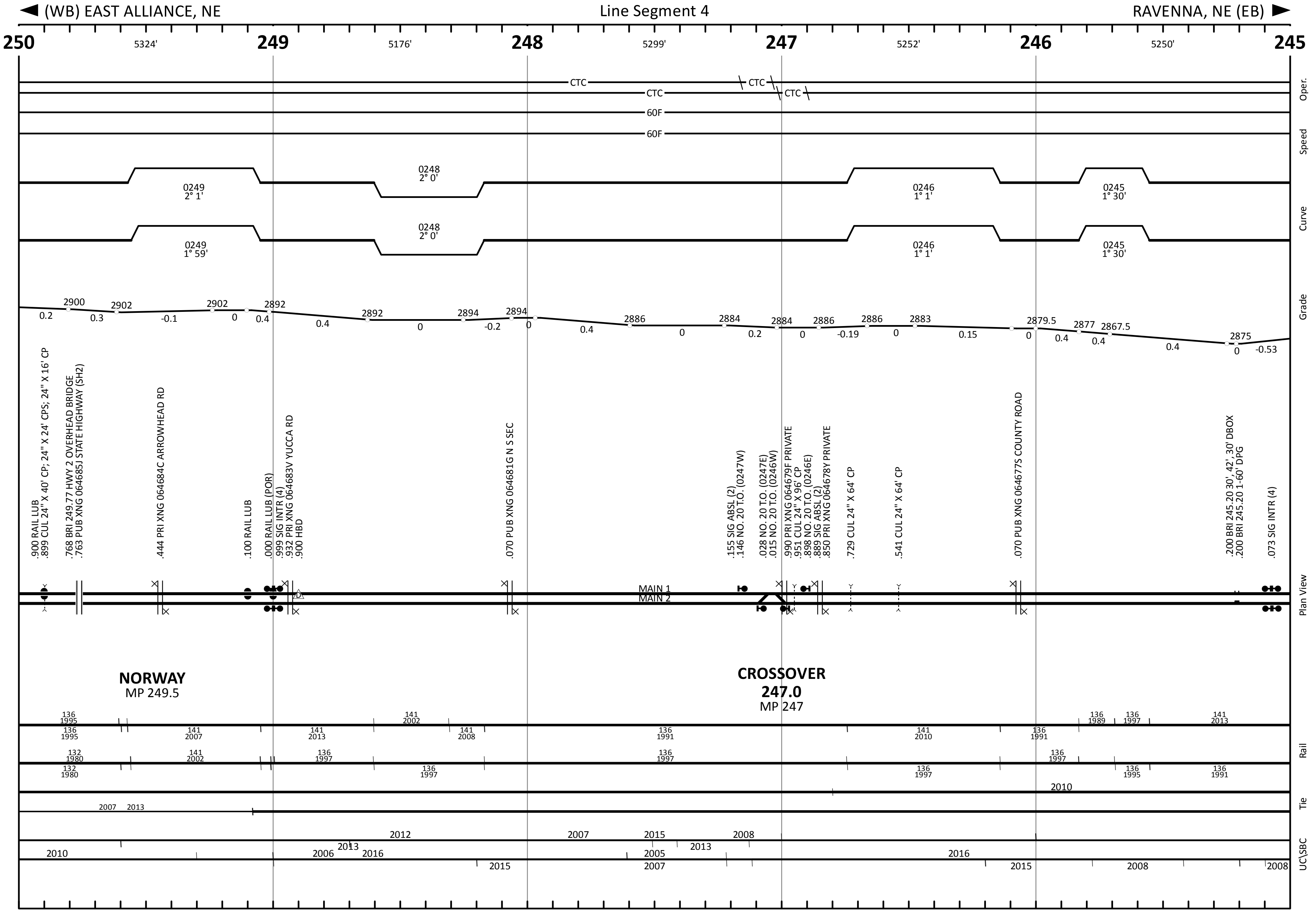

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System Maintenance and Planning

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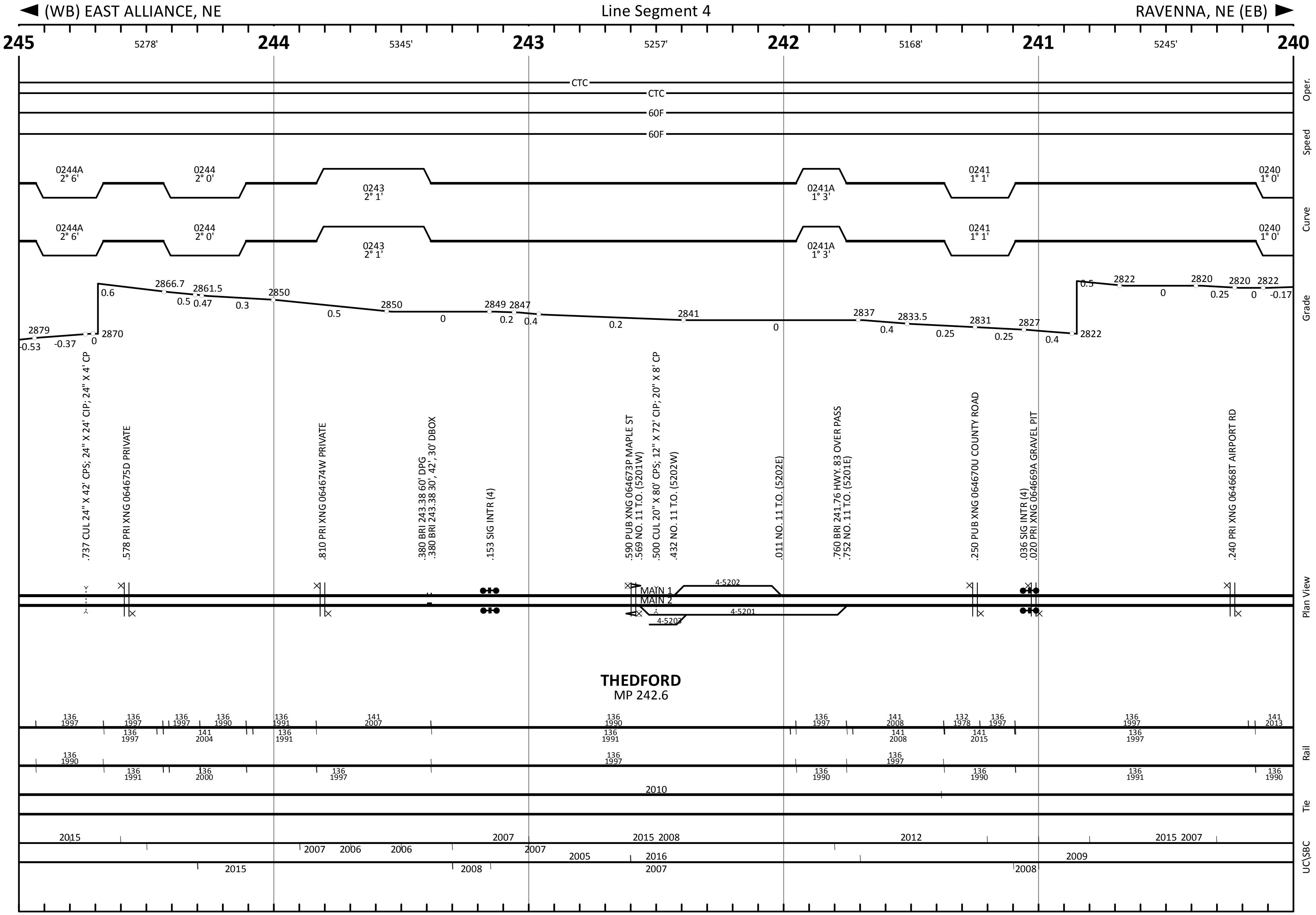
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018



BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

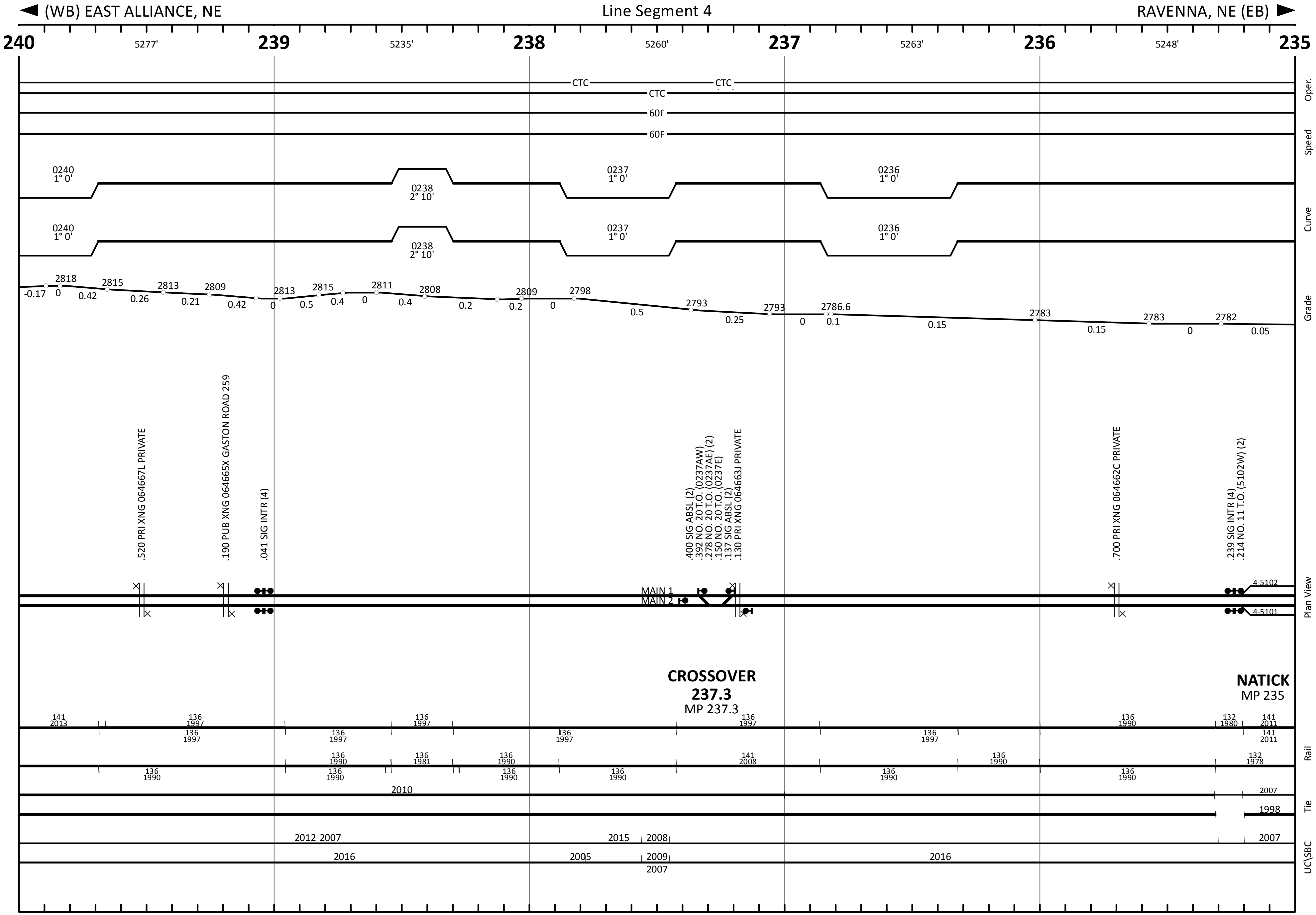
Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018 Page 34 of 61



System Maintenance and Planning

Sand Hills Subdivision

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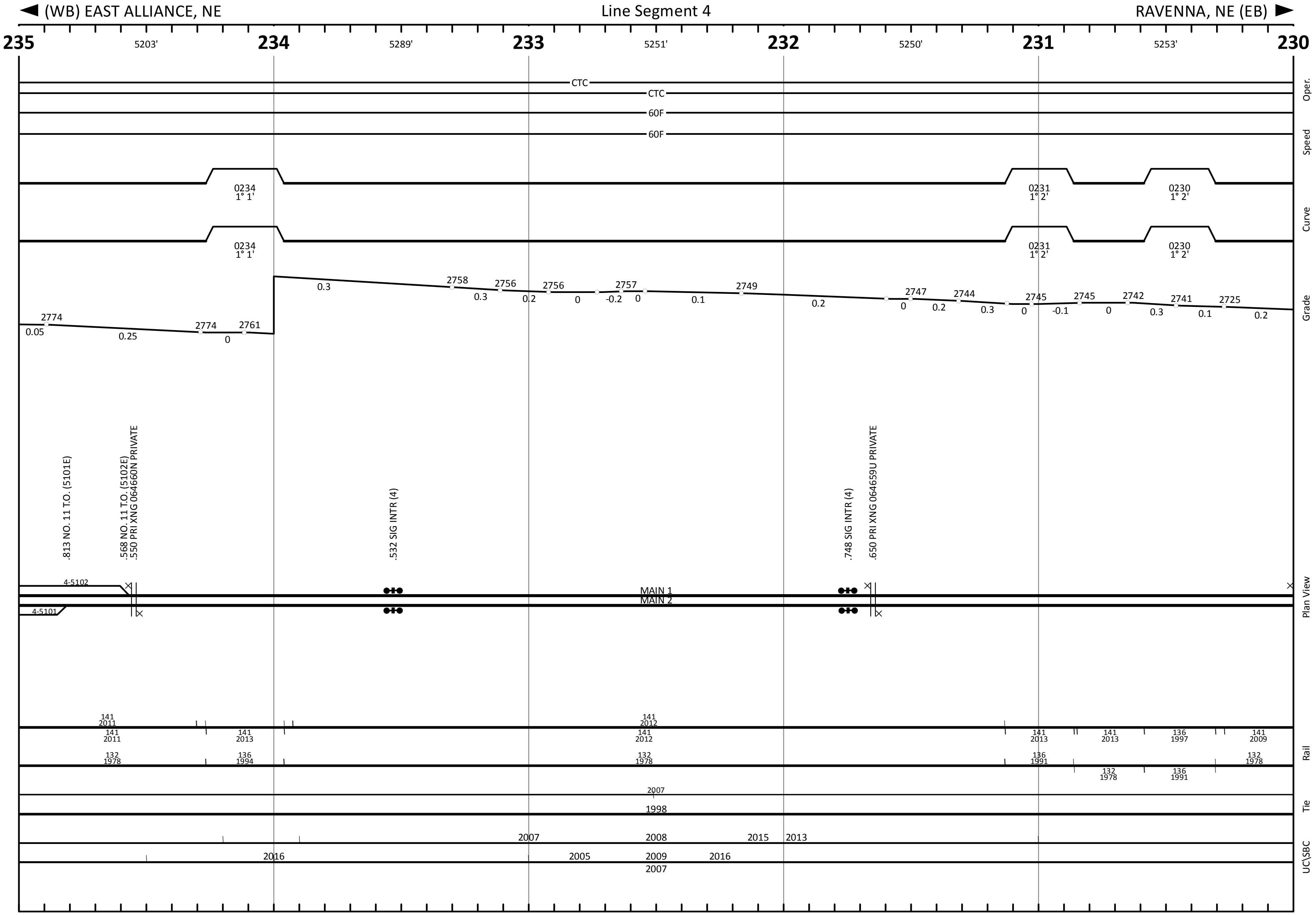
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 16, 2018



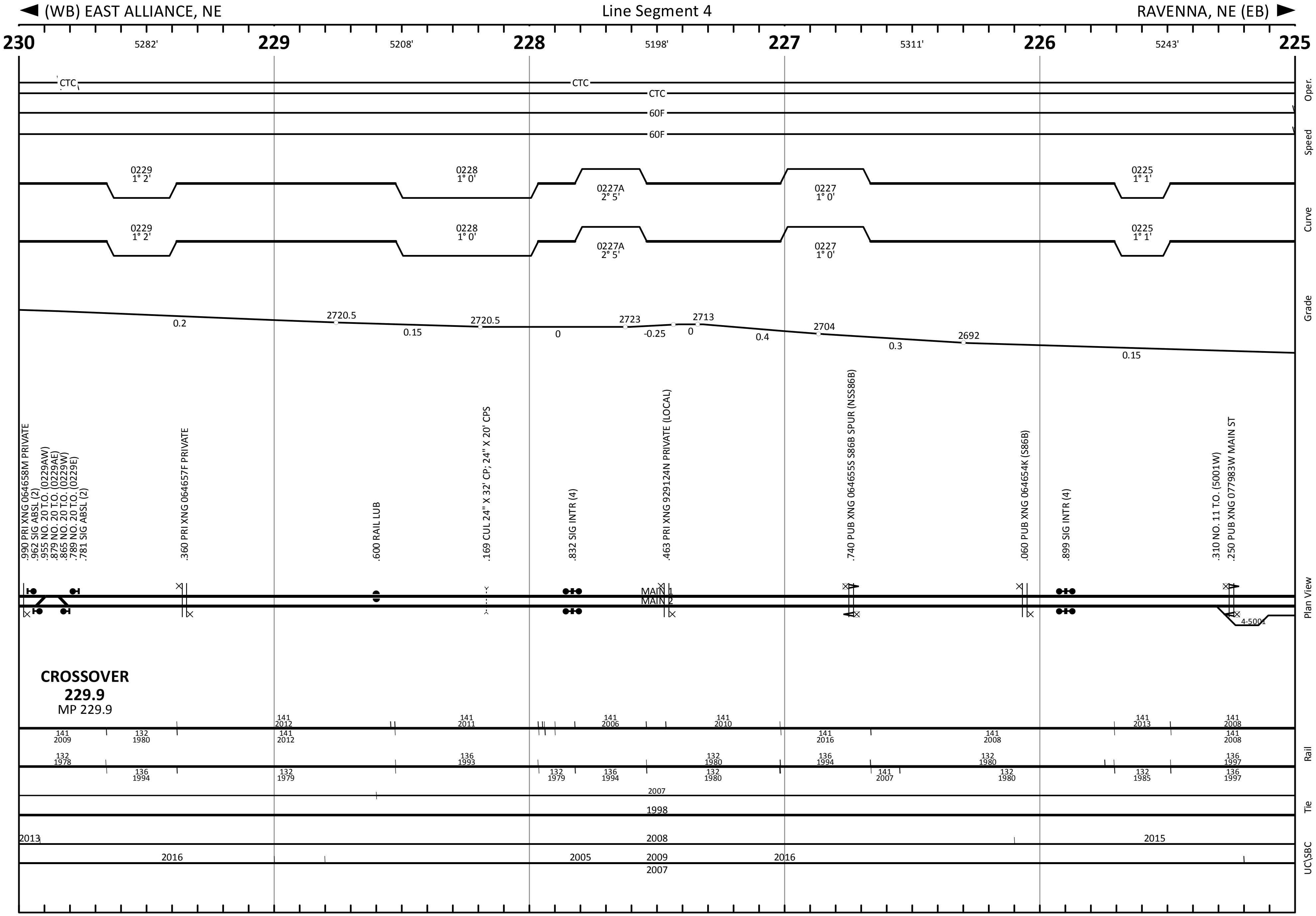
RAILWAY
System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 16, 2018

◄ (WB) EAST ALLIANCE, NE
Line Segment 4
RAVENNA, NE (EB) ►
230
5282'
229
5208'
228
5198'
227
5311'
226
5243'
225
Oper.
CTC
CTC
CTC
Speed
60F
60F
Curve
0229 1° 2'
0228 1° 0'
0227A 2° 5'
0227 1° 0'
0225 1° 1'
0229 1° 2'
0228 1° 0'
0227A 2° 5'
0227 1° 0'
0225 1° 1'
Grade
0.2
2720.5
0.15
2720.5
0
2723
-0.25
0
2713
0.4
2704
0.3
2692
0.15
.990 PRI XNG 064658M PRIVATE
.962 SIG ABSL (2)
.955 NO. 20 T.O. (0229AW)
.879 NO. 20 T.O. (0229AE)
.865 NO. 20 T.O. (0229W)
.789 NO. 20 T.O. (0229E)
.781 SIG ABSL (2)
.360 PRI XNG 064657F PRIVATE
.600 RAIL LUB
.169 CUL 24" X 32' CP; 24" X 20' CPS
.832 SIG INTR (4)
.463 PRI XNG 929124N PRIVATE (LOCAL)
.740 PUB XNG 064655S S86B SPUR (NS86B)
.060 PUB XNG 064654K (S86B)
.899 SIG INTR (4)
.310 NO. 11 T.O. (5001W)
.250 PUB XNG 077983W MAIN ST
Plan View
MAIN 1
MAIN 2
4-5001
CROSSOVER
229.9
MP 229.9
Rail
141 2012
141 2011
141 2006
141 2010
141 2013
141 2008
141 2009
132 1980
141 2012
141 2016
141 2008
141 2008
132 1978
136 1993
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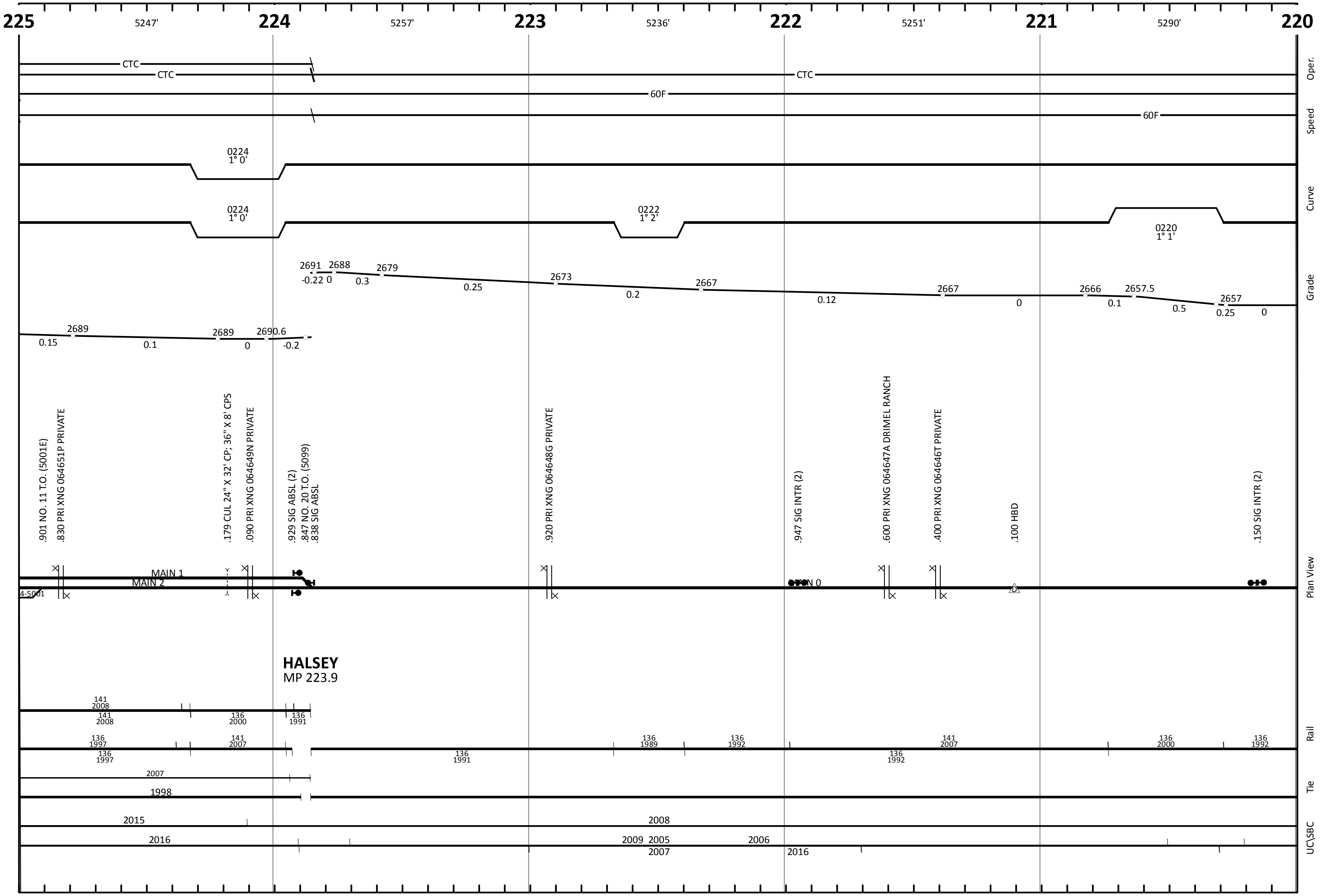
◄ (WB) EAST ALLIANCE, NE Line Segment 4 RAVENNA, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

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Engineering Track Chart

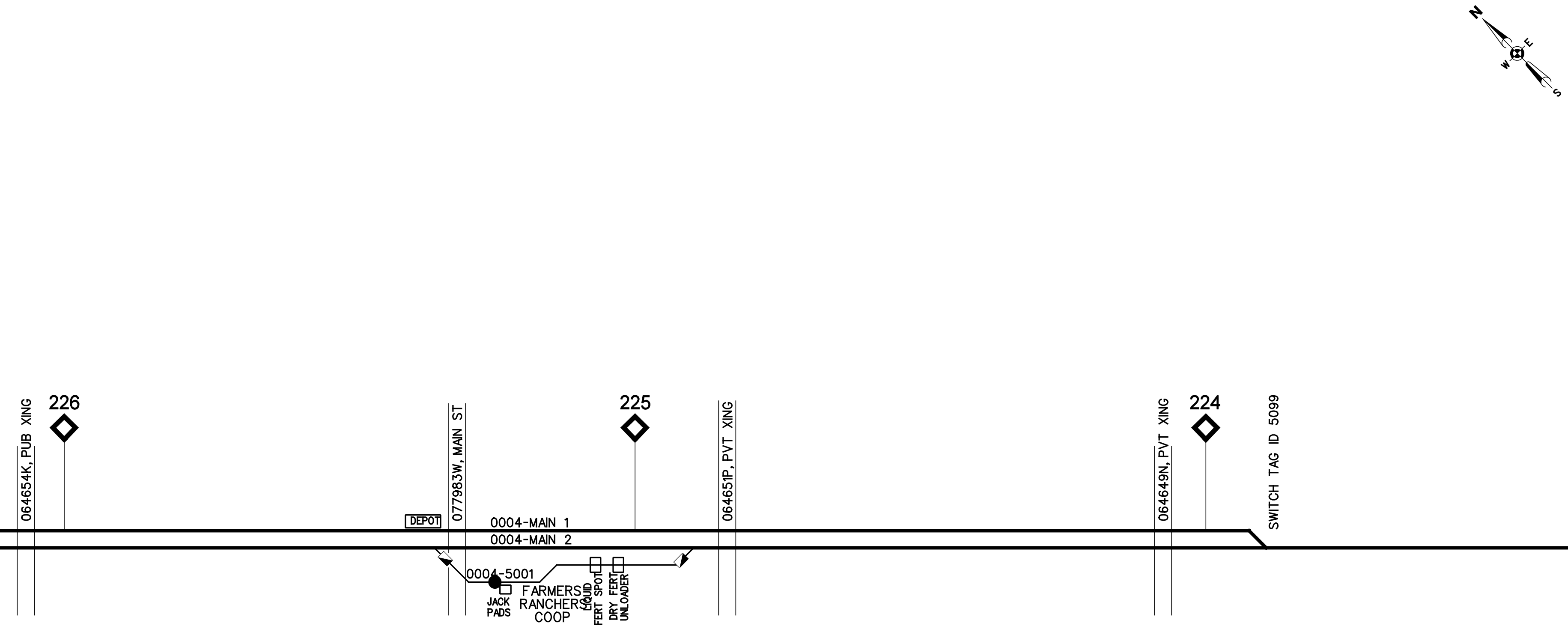
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018

HALSEY, NE
Sand Hills Subdivision

← East Alliance, NE

Ravenna, NE →



BNSF RAILWAY

REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
SPECIAL CONDITIONS (ITEM #7)
FOR ADDITIONAL QUESTIONS ON PHYSICAL CHARACTERISTICS, CONTACT A LOCAL DIVISION MANAGER
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

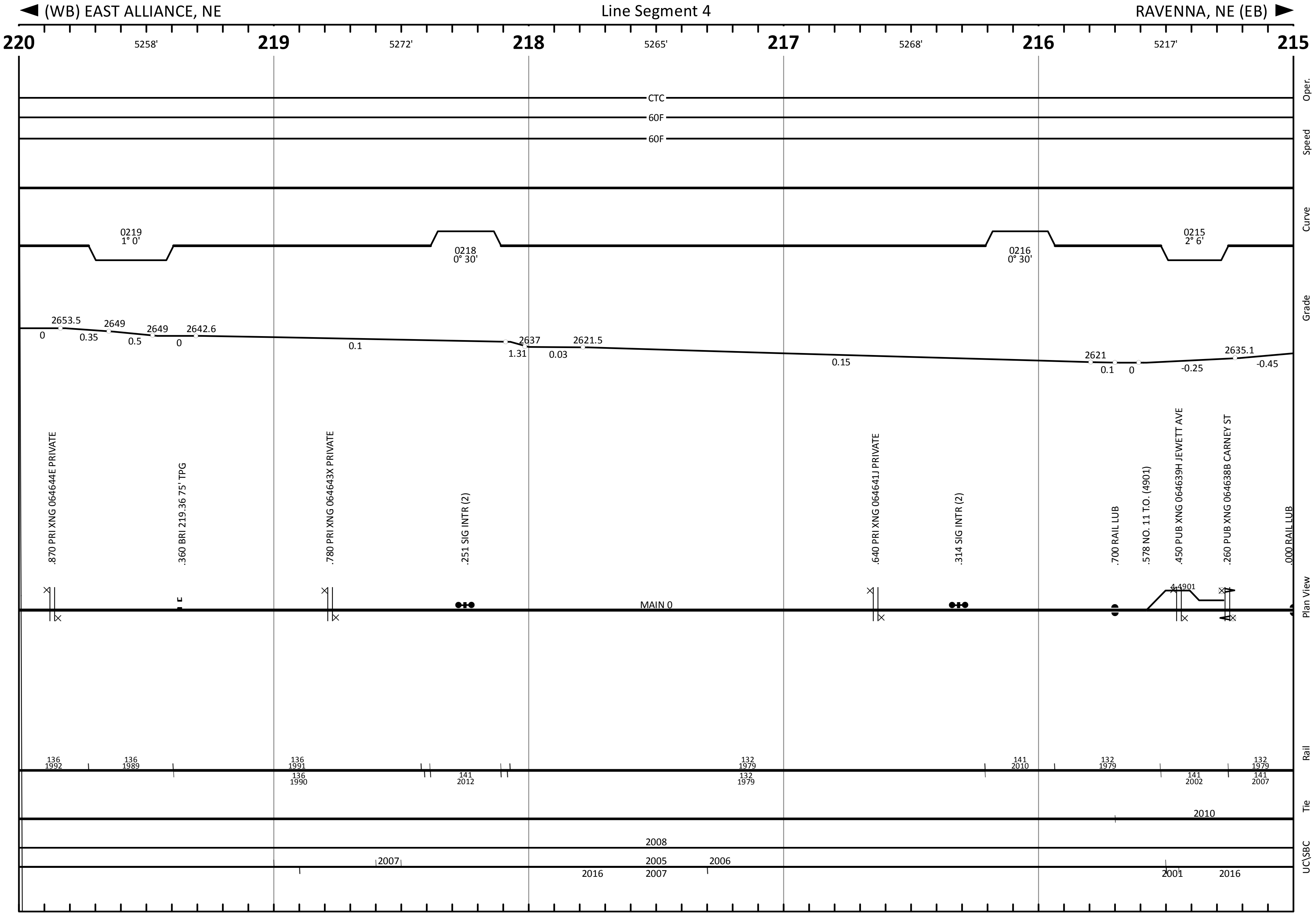
TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: HALSEY
FSAC: 30224
REVISED: 11/7/2014
TEAM: HALS50045.DGN
TRK CHT: SAN039.DGN
TEAM PG 045



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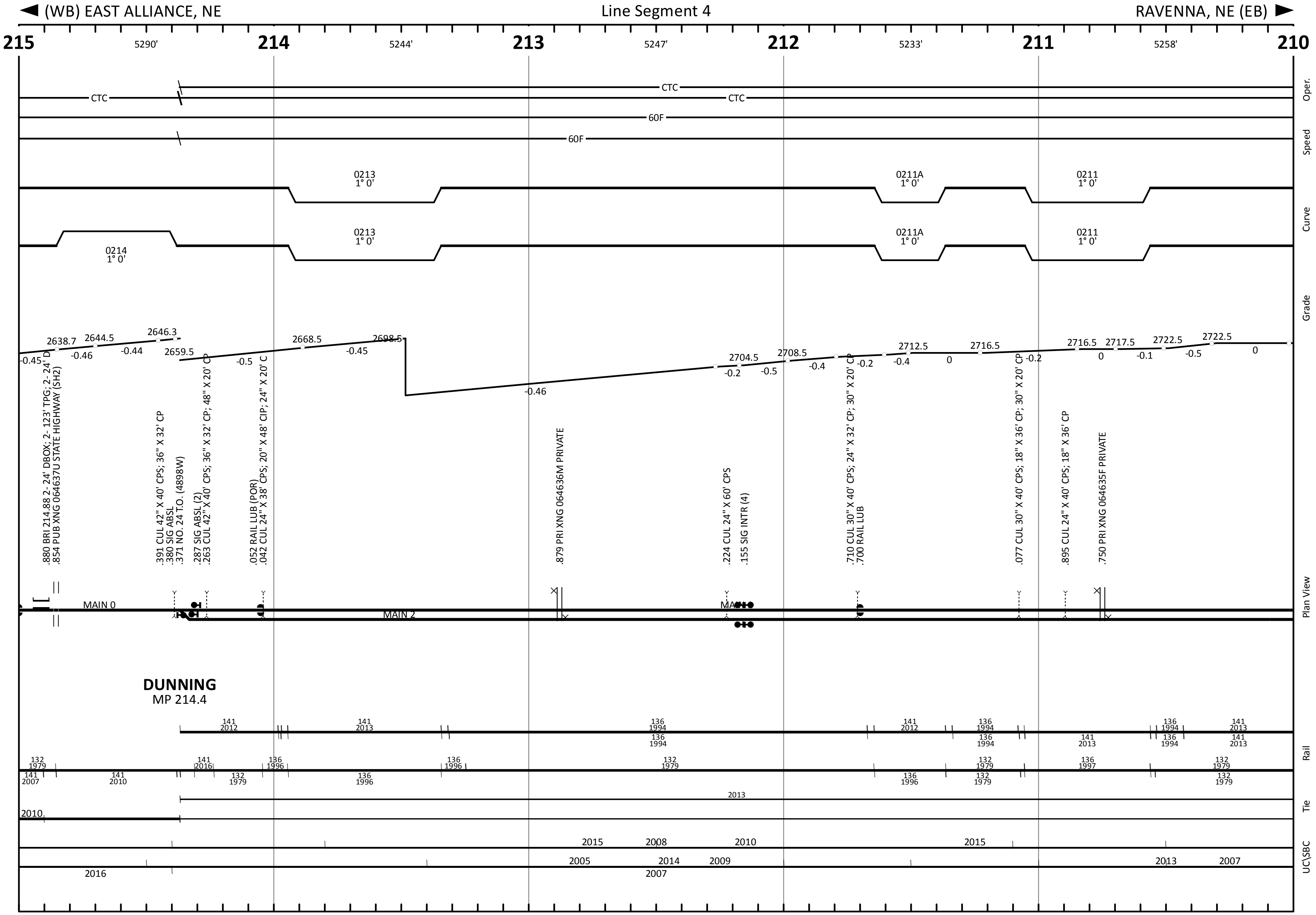

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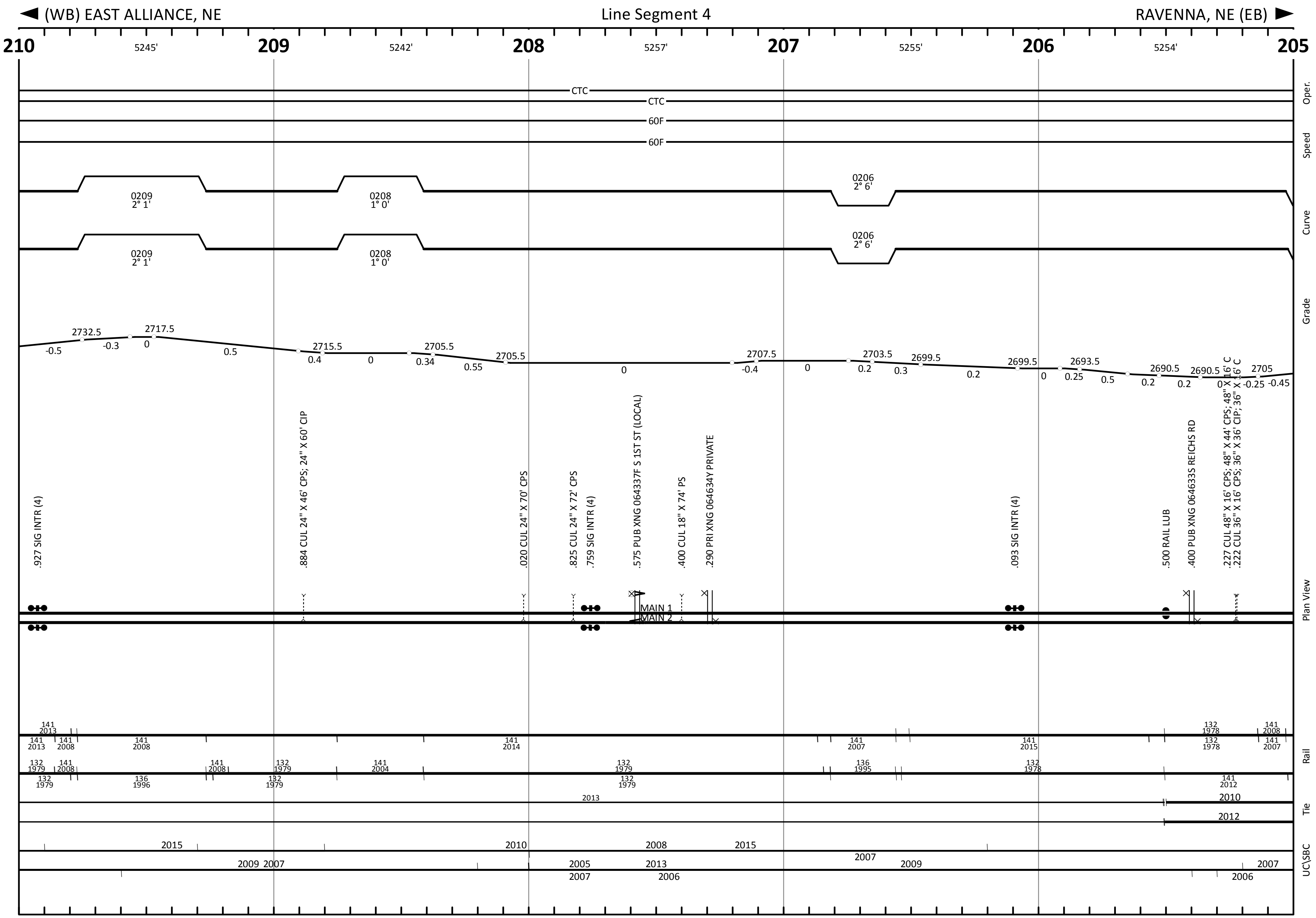

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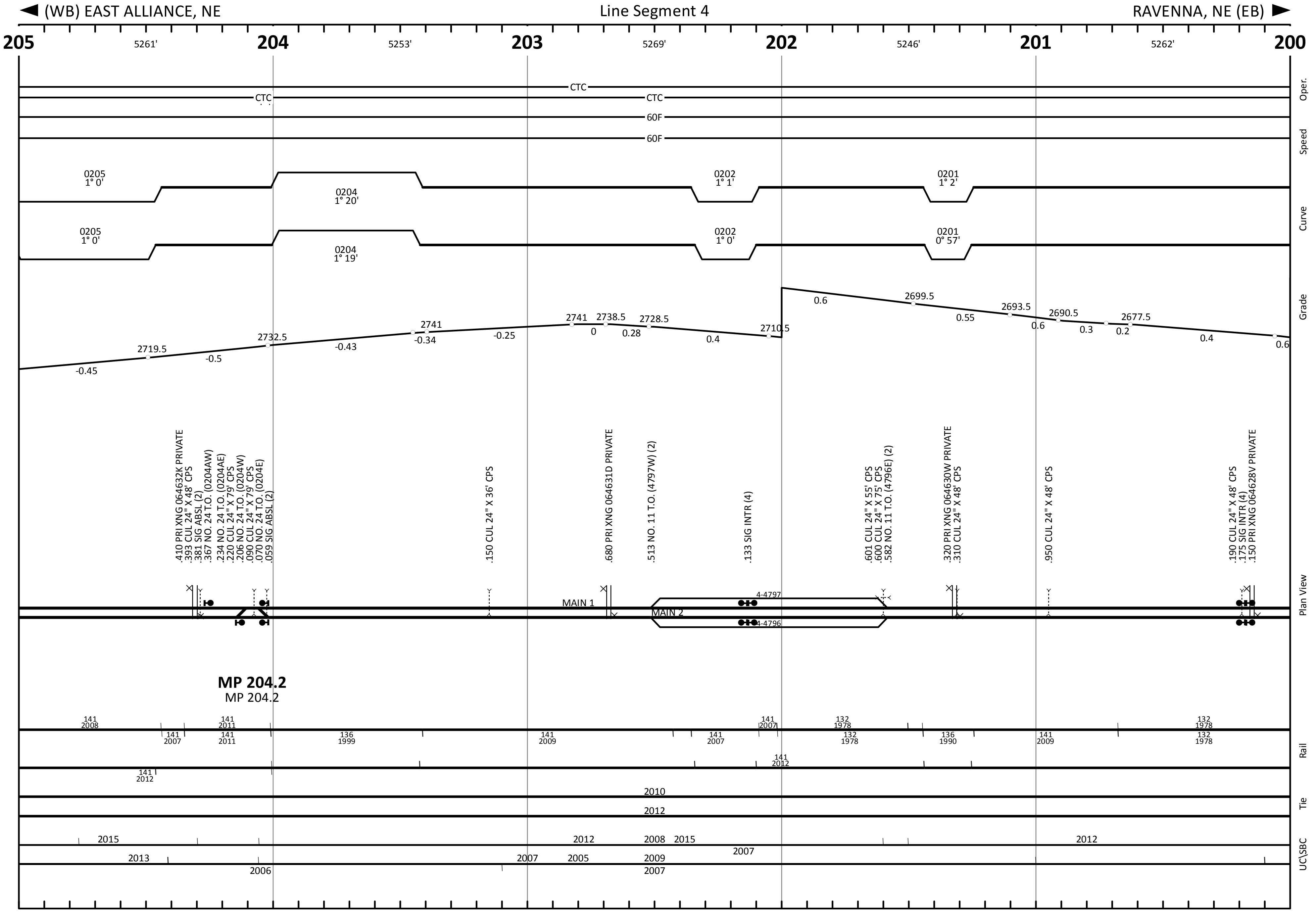

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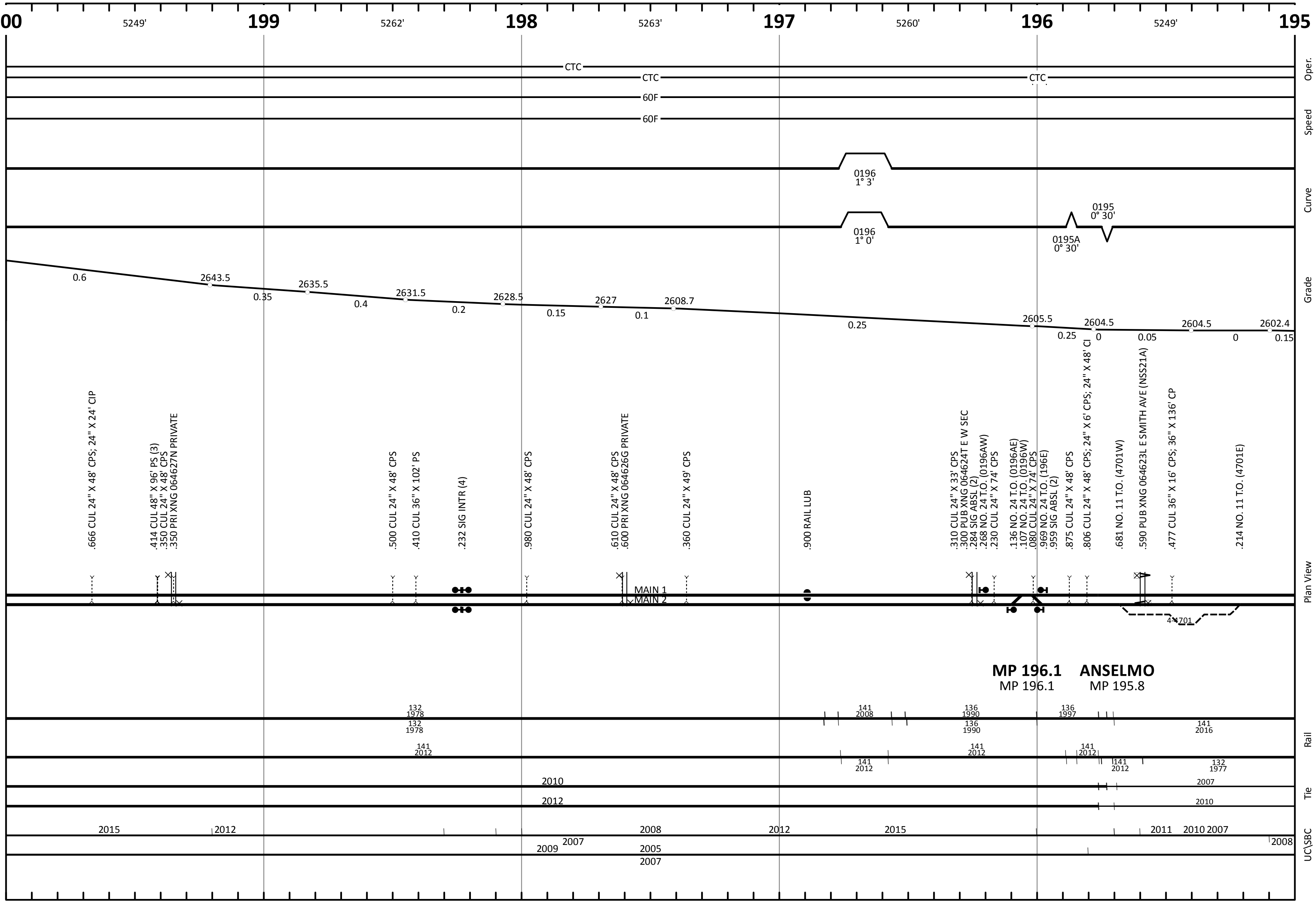

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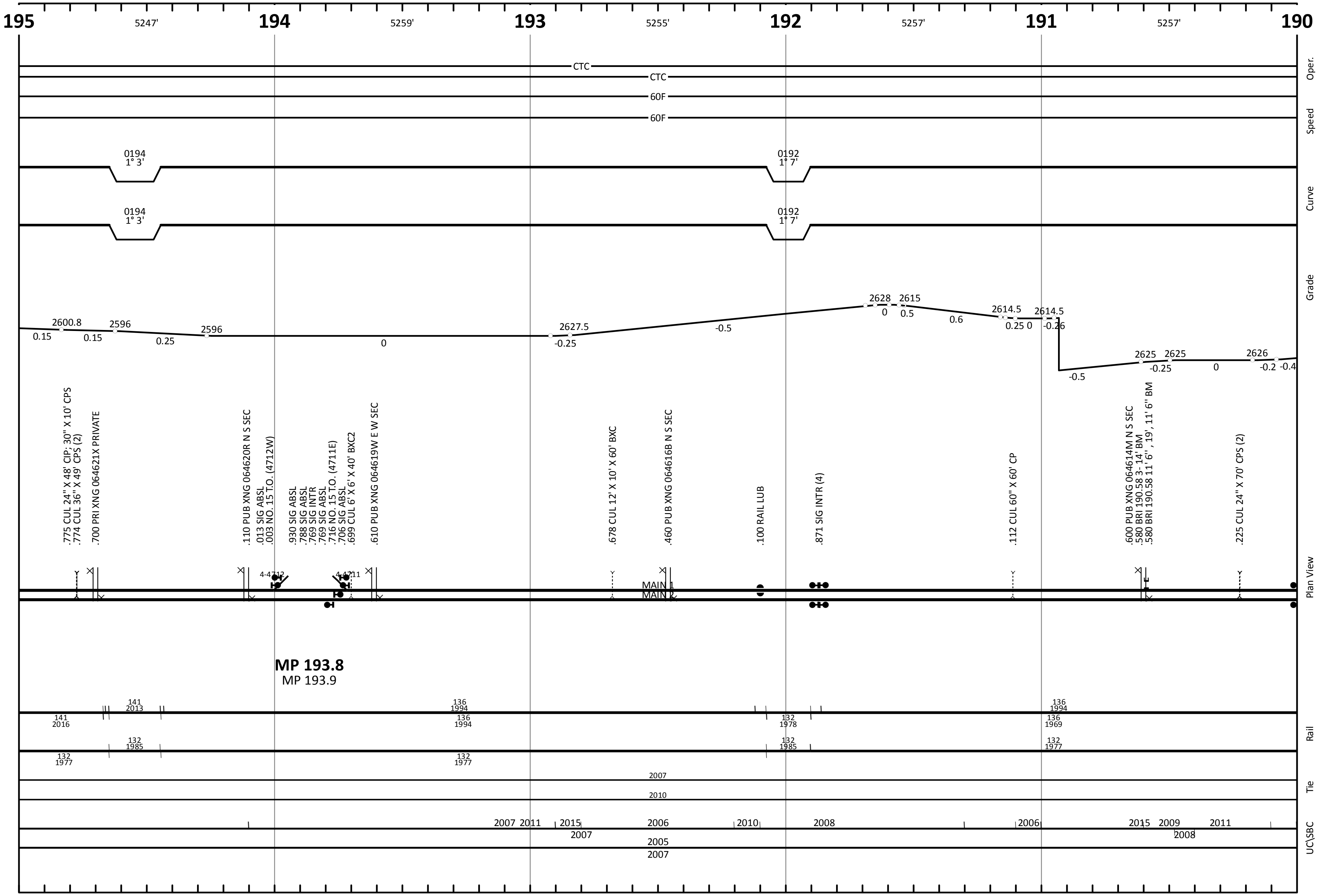

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Revised to July 16, 2018

ANSELMO, NE
Sand Hills Subdivision

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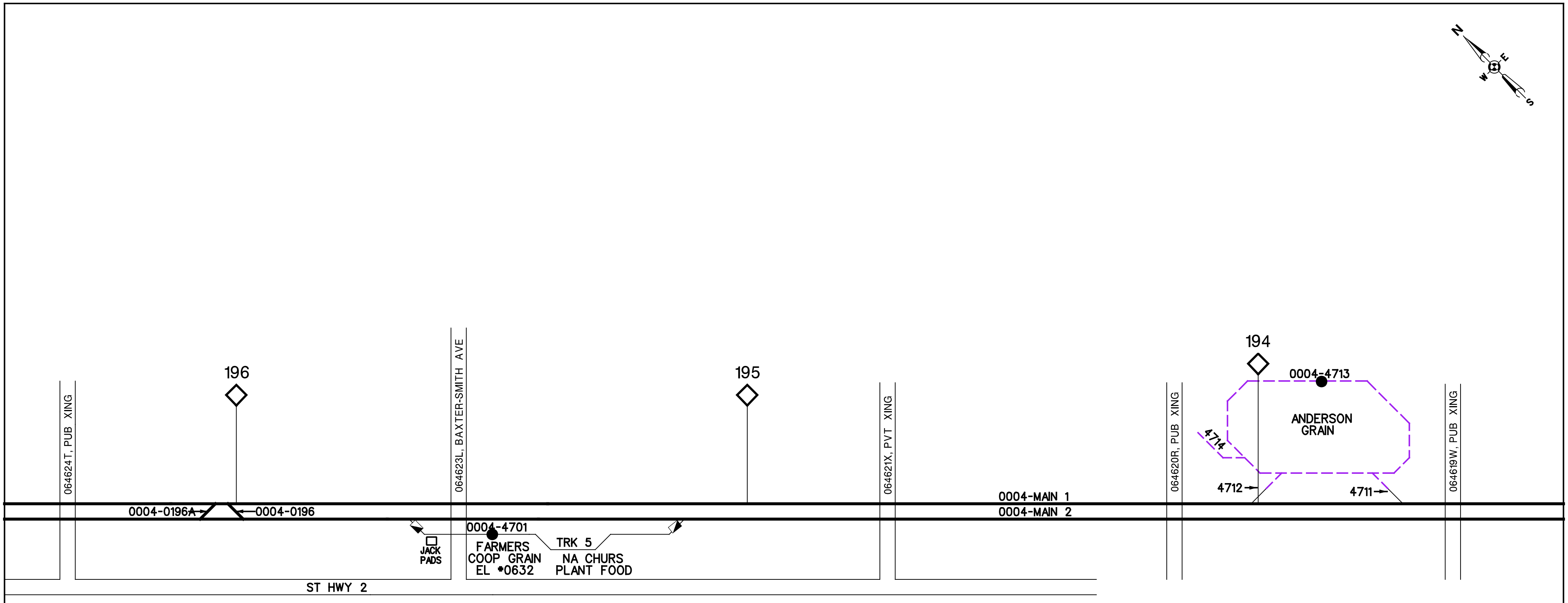
Ravenna, NE →



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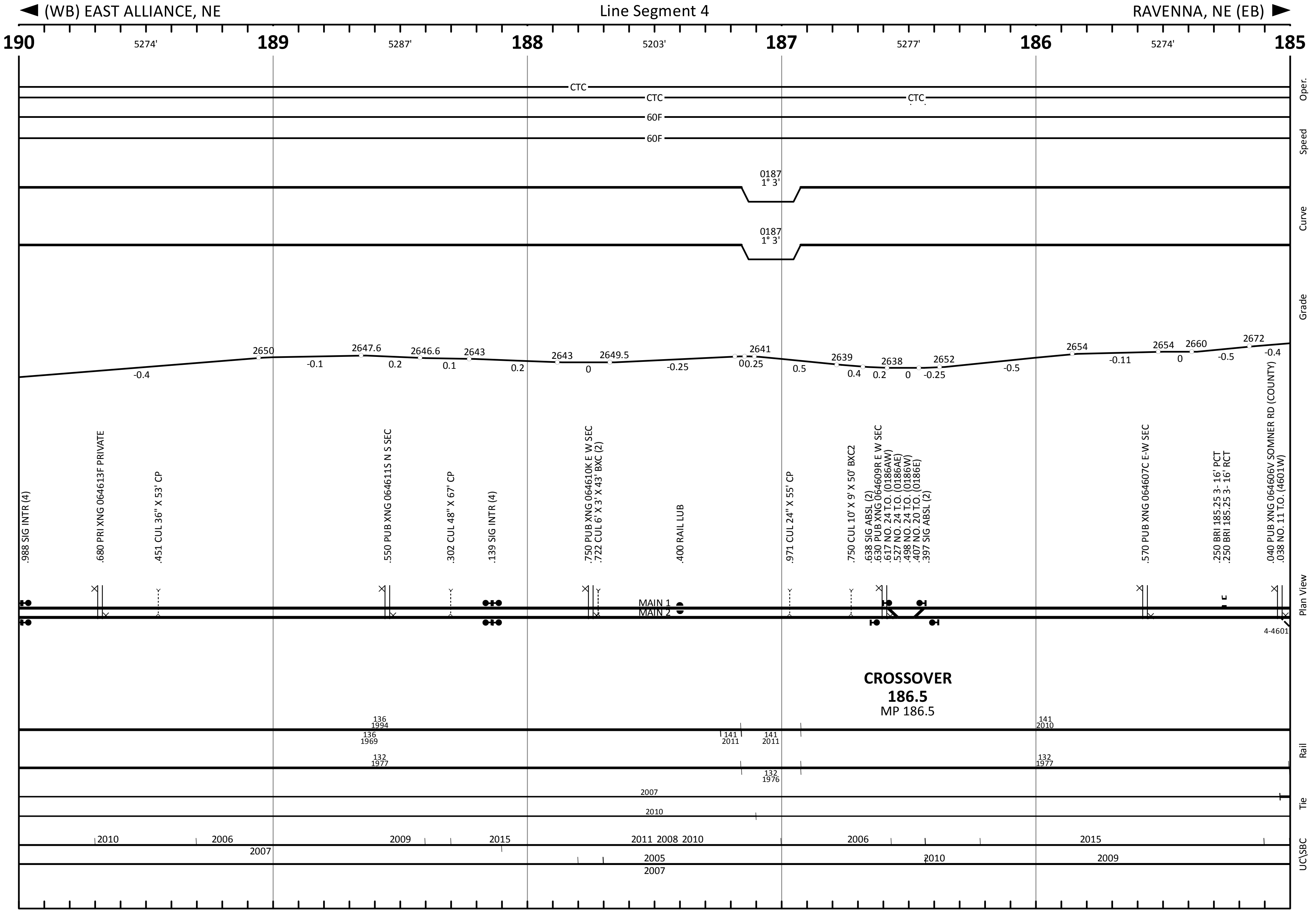
—◆—◆—	INDUSTRY OWNED & BNSF MAINT	▬▬▬	TRACKAGE RIGHTS
– – – –	IND OWNED & MAINT	─┼─┼─	FOREIGN TRACK
—●—●—	INDUSTRY MAINT & BNSF OWNED (LEASE)		
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT		
◪	DERAIL		

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: ANSELM
FSAC: 30194
REVISED: 10/25/2017
TEAM: ANSE47051.DGN
TRK CHT: SAN046.DGN



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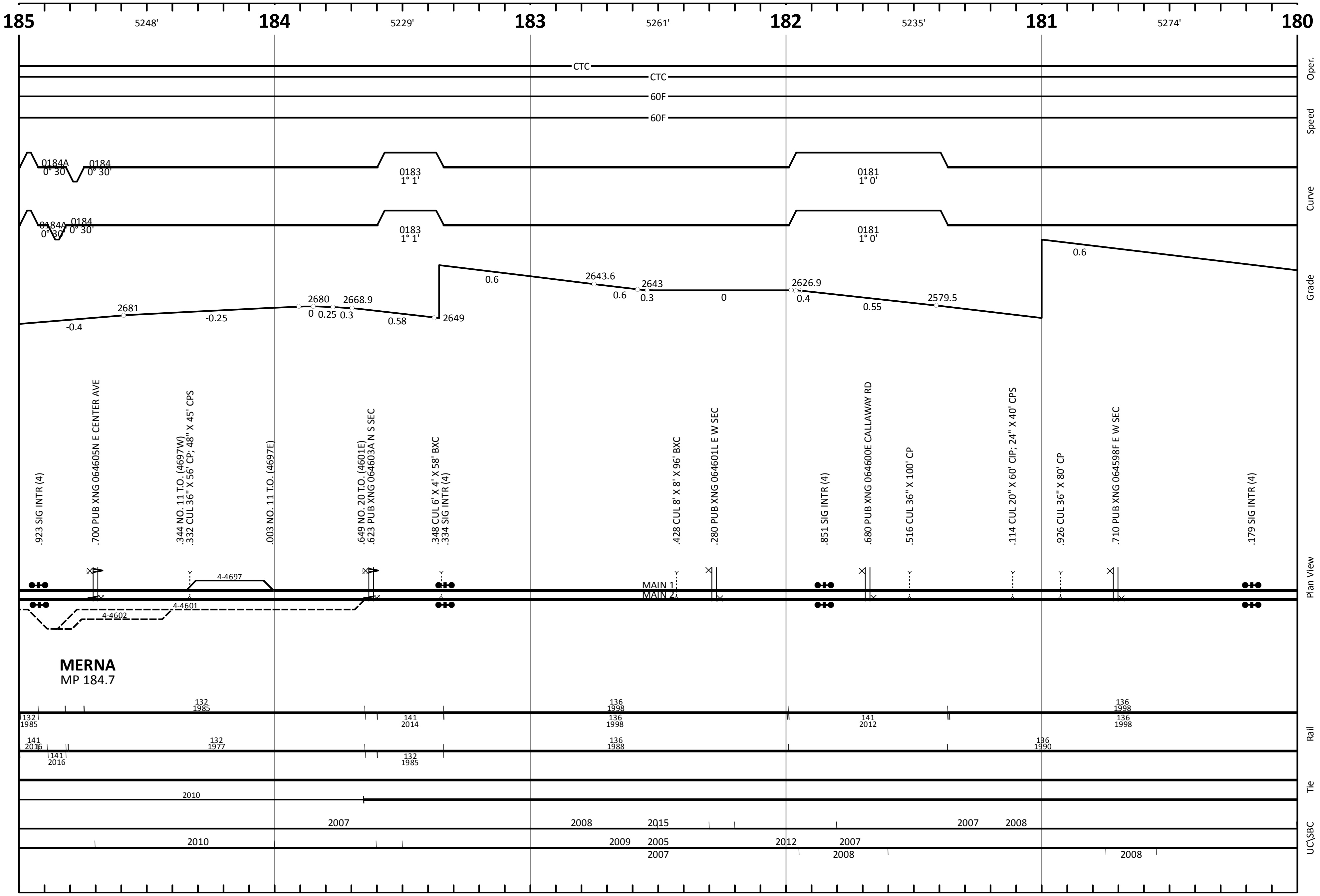
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 16, 2018

◄ (WB) EAST ALLIANCE, NE Line Segment 4 RAVENNA, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division

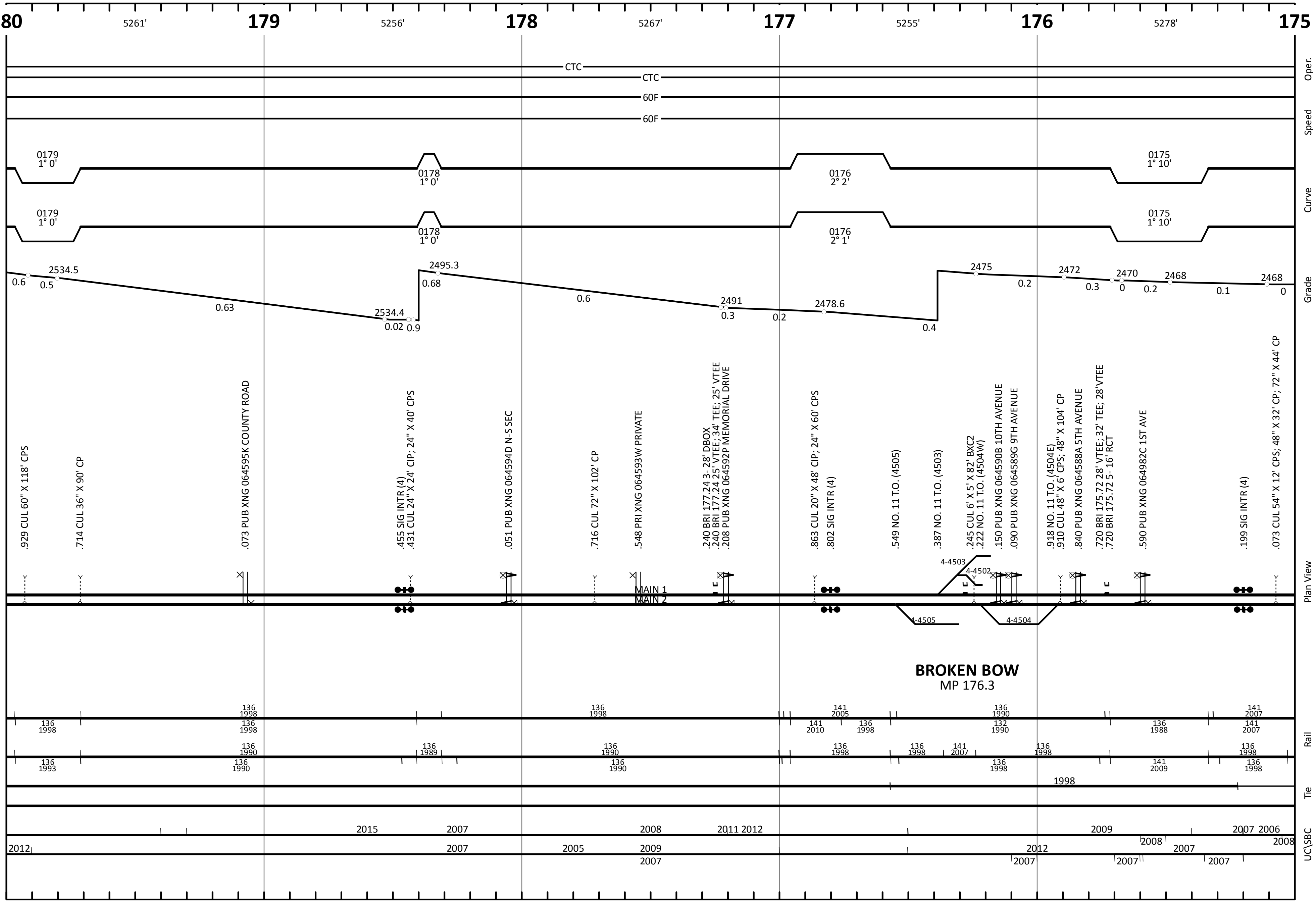
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018

◀ (WB) EAST ALLIANCE, NE Line Segment 4 RAVENNA, NE (EB) ▶



BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

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Powder River East Engineering Division

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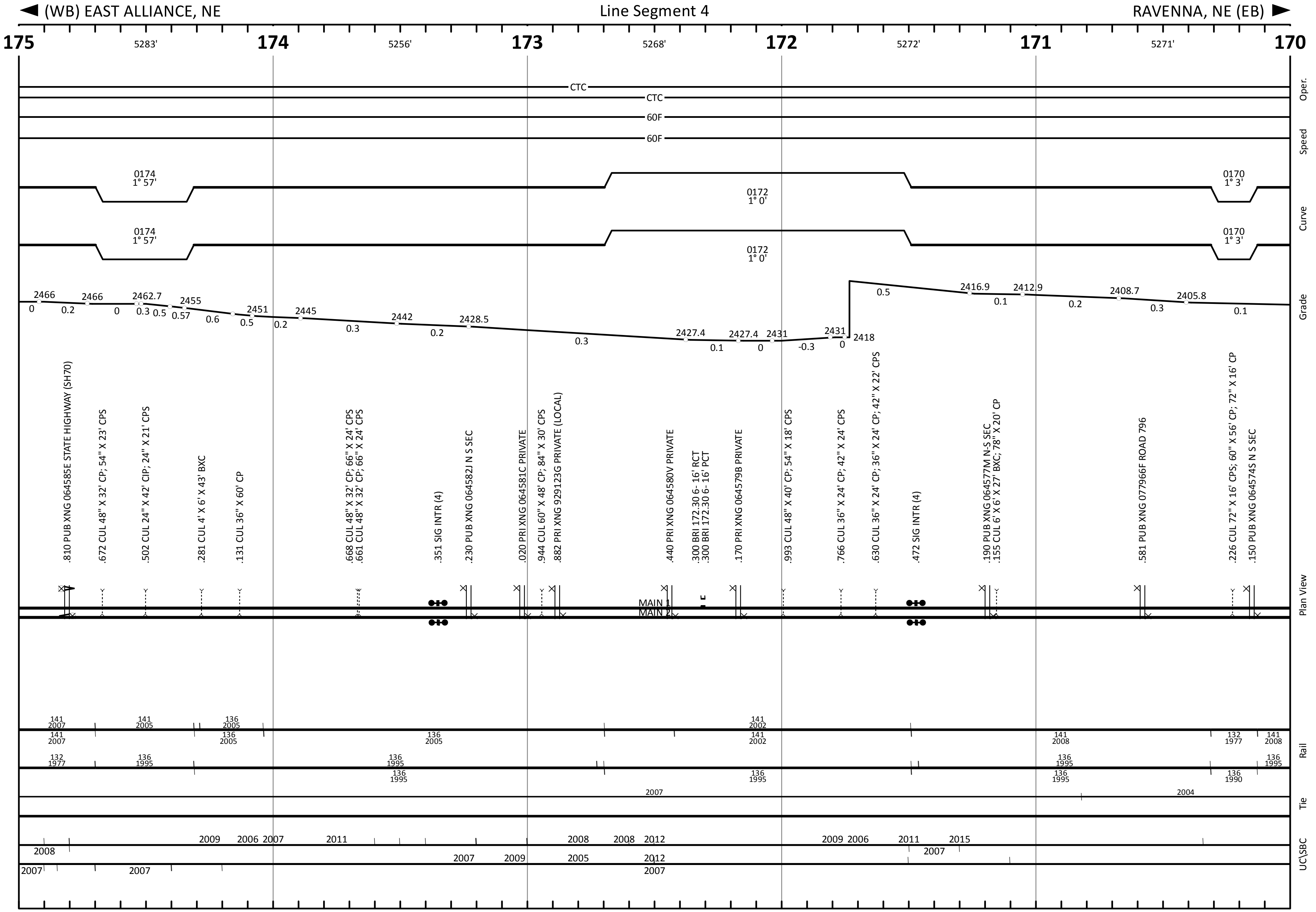
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018

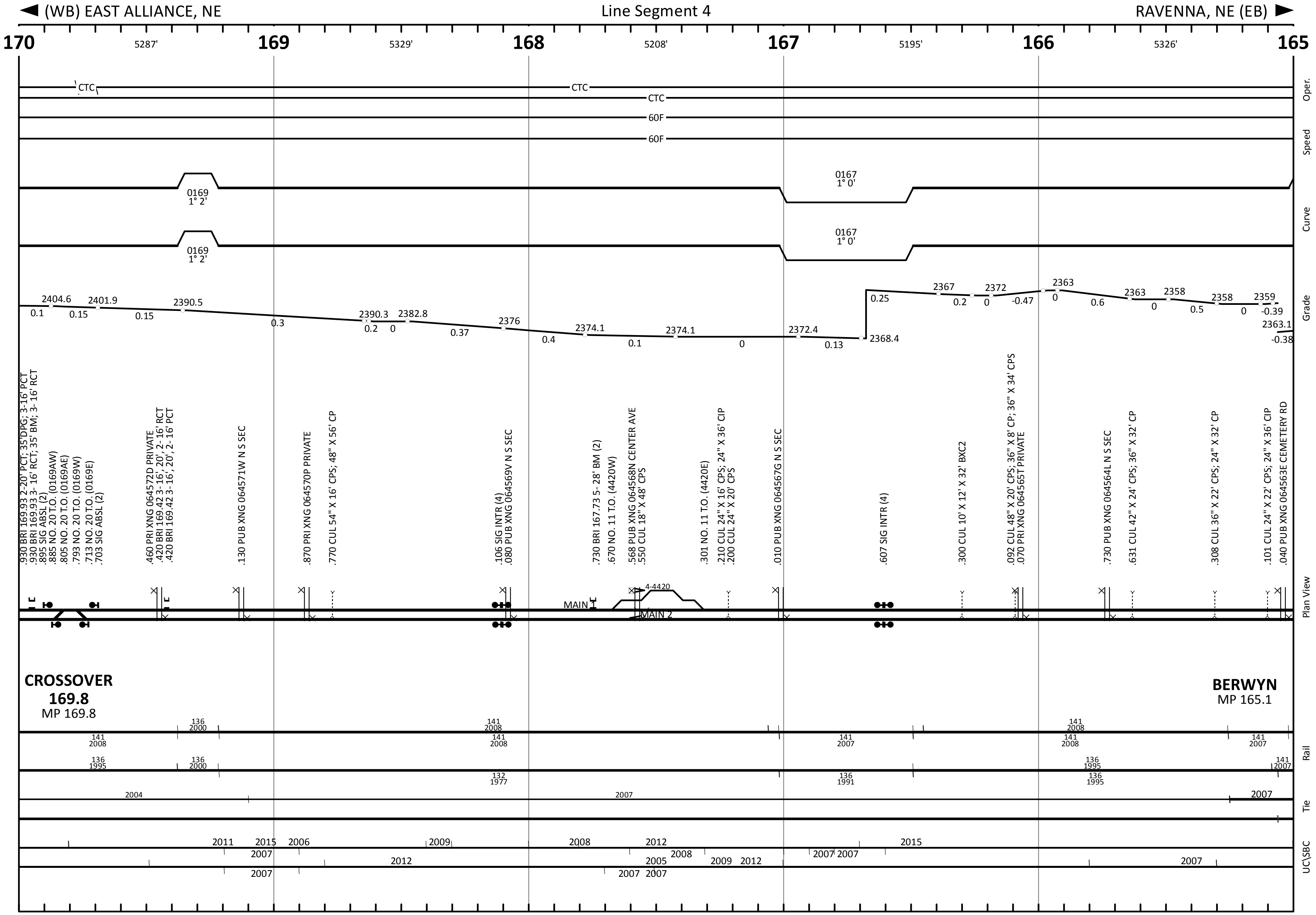


Sand Hills Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com



BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division

Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018

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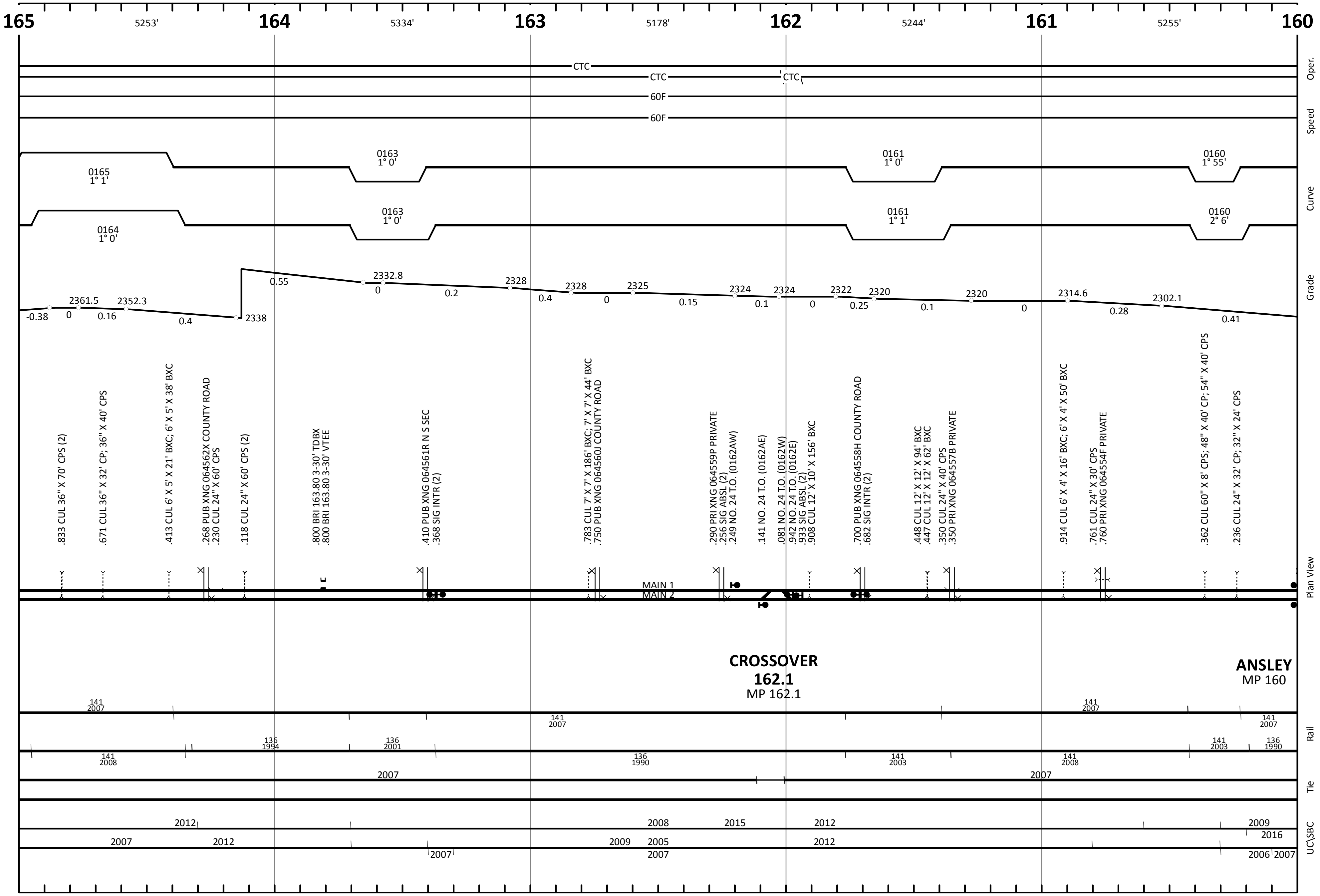

BNSF RAILWAY
System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division
Powder River East Engineering Division

Engineering Track Chart

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Revised to July 16, 2018

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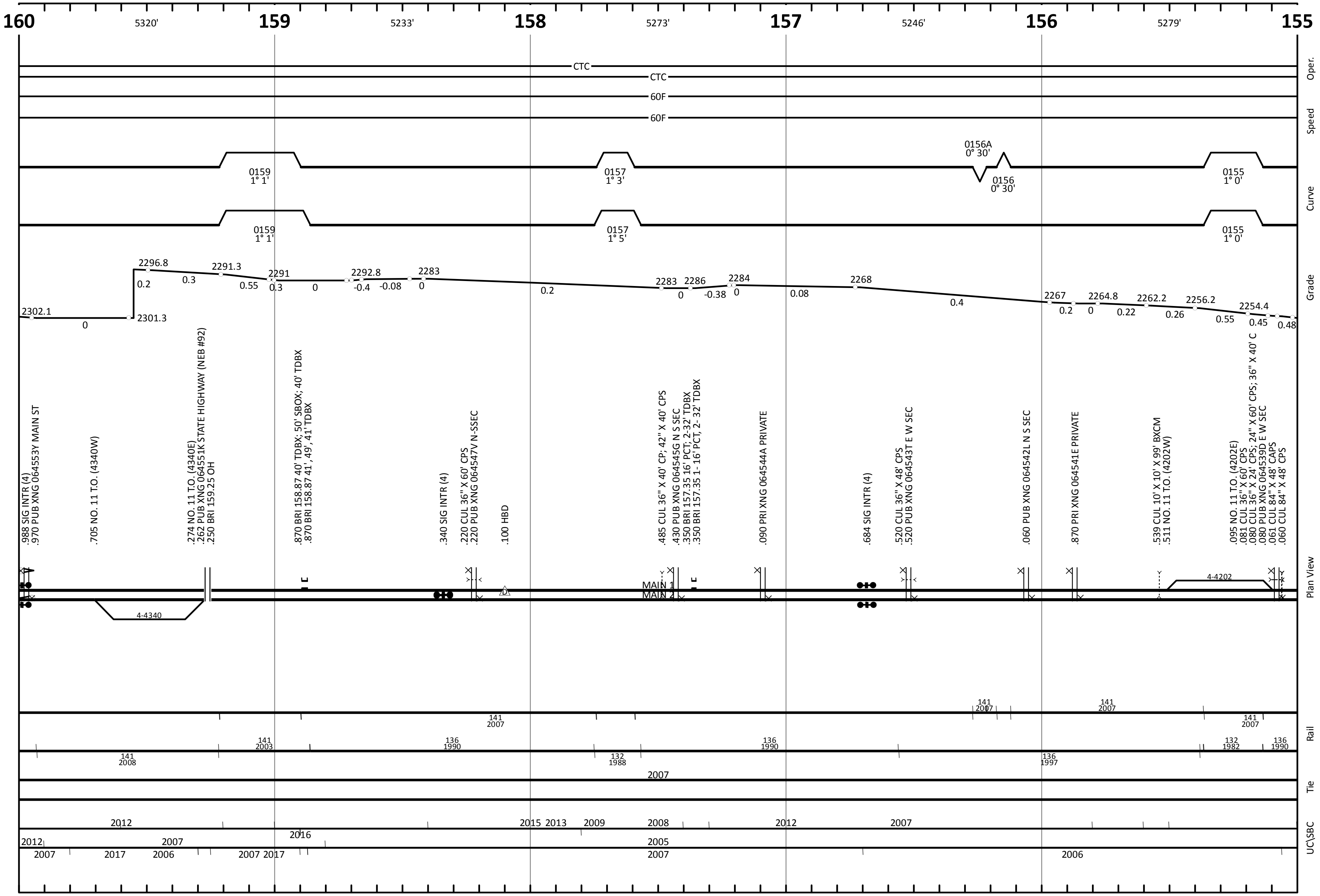


BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division

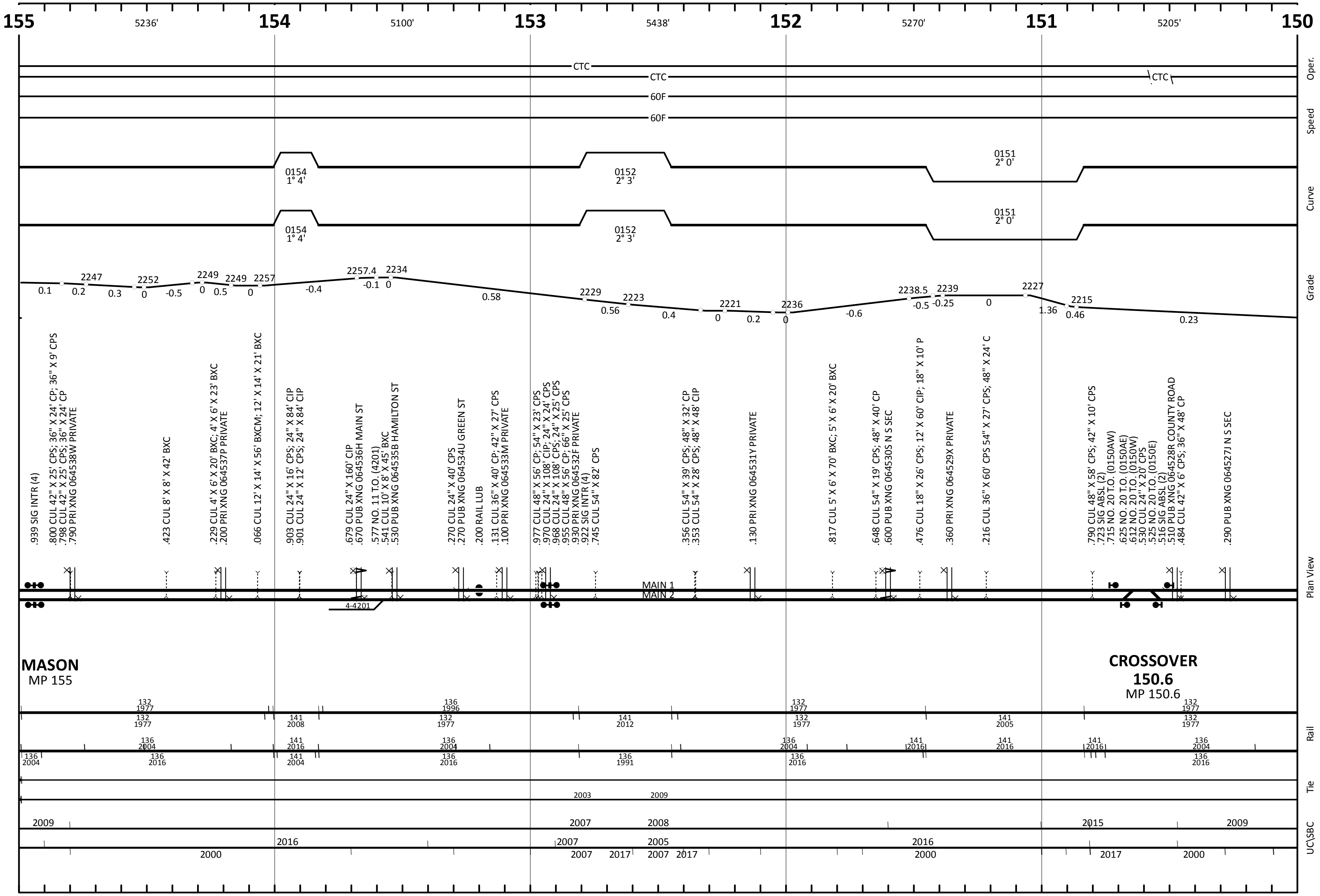
Powder River East Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 16, 2018 Page 53 of 61

◄ (WB) EAST ALLIANCE, NE Line Segment 4 RAVENNA, NE (EB) ►



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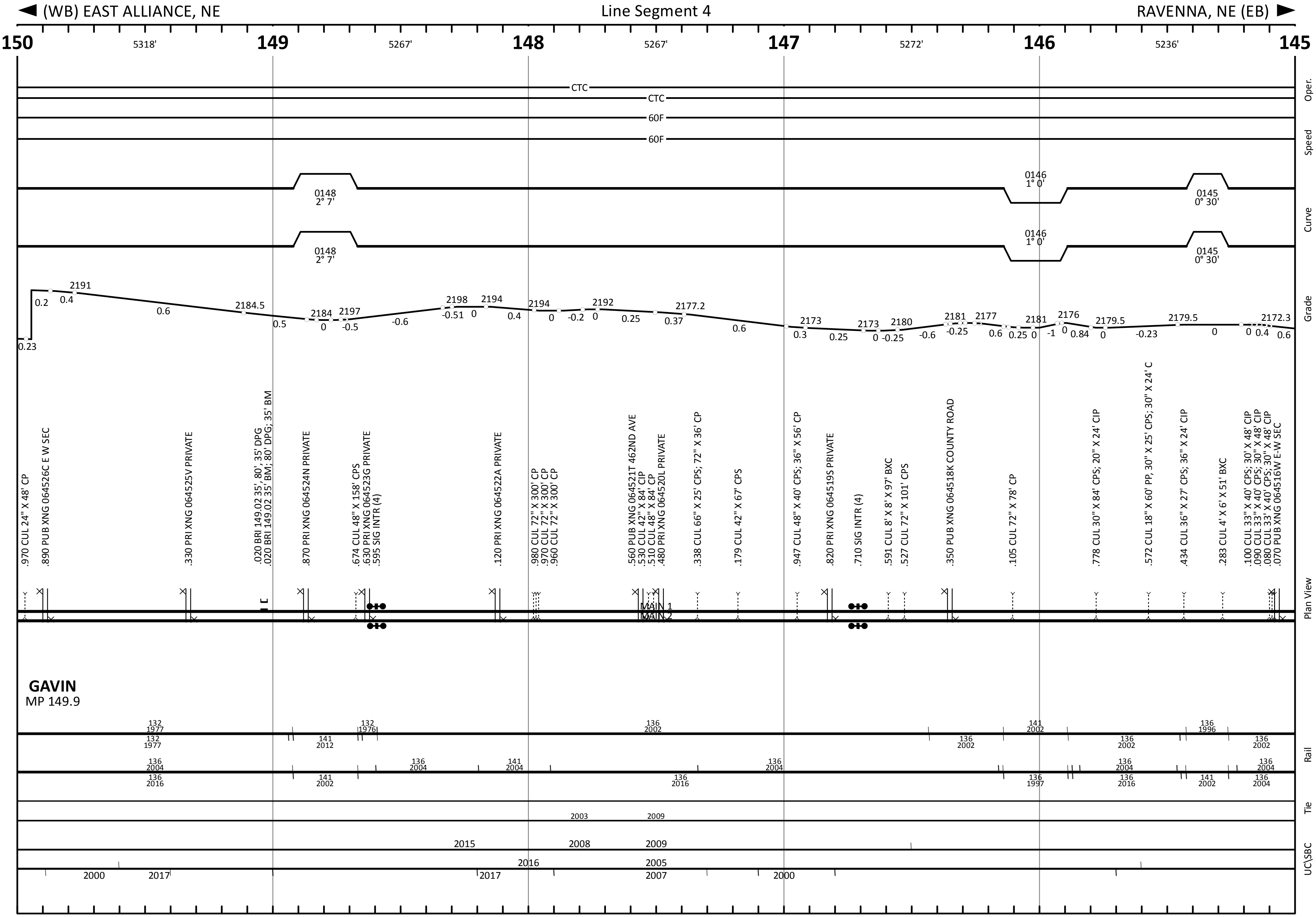

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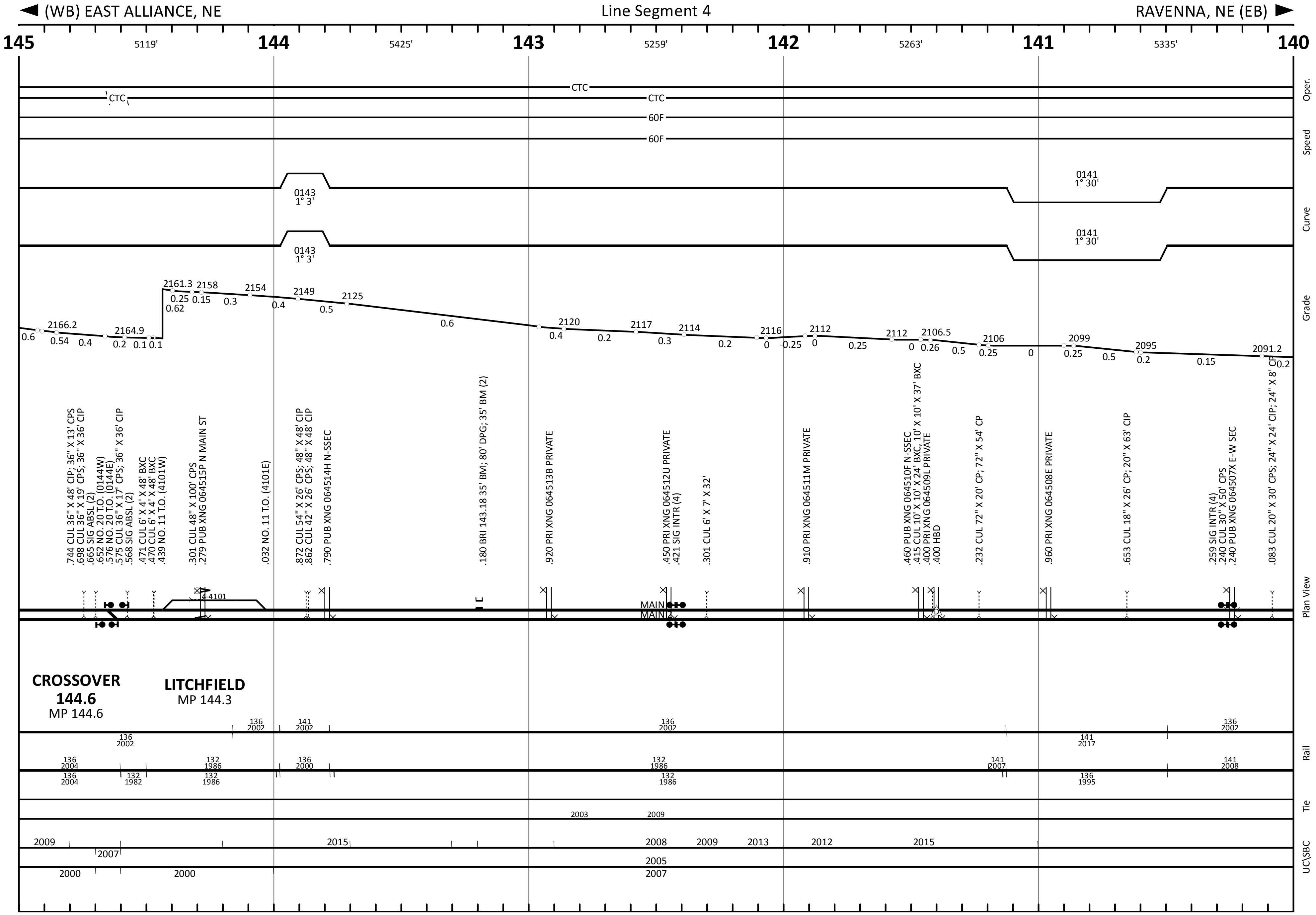


BNSF RAILWAY

System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division
Powder River East Engineering Division

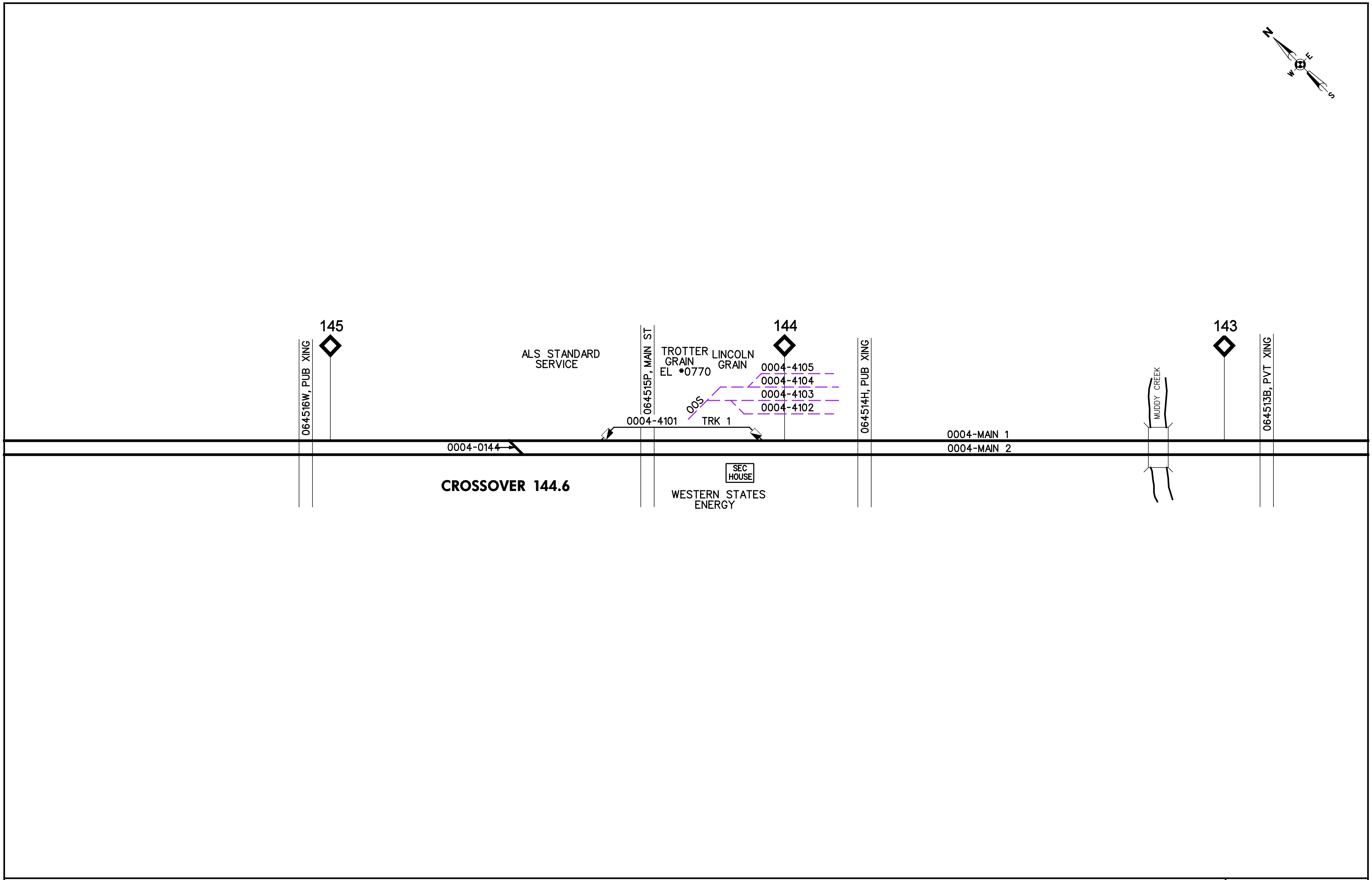
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

LITCHFIELD, NE
Sand Hills Subdivision

← East Alliance, NE

Ravenna, NE →



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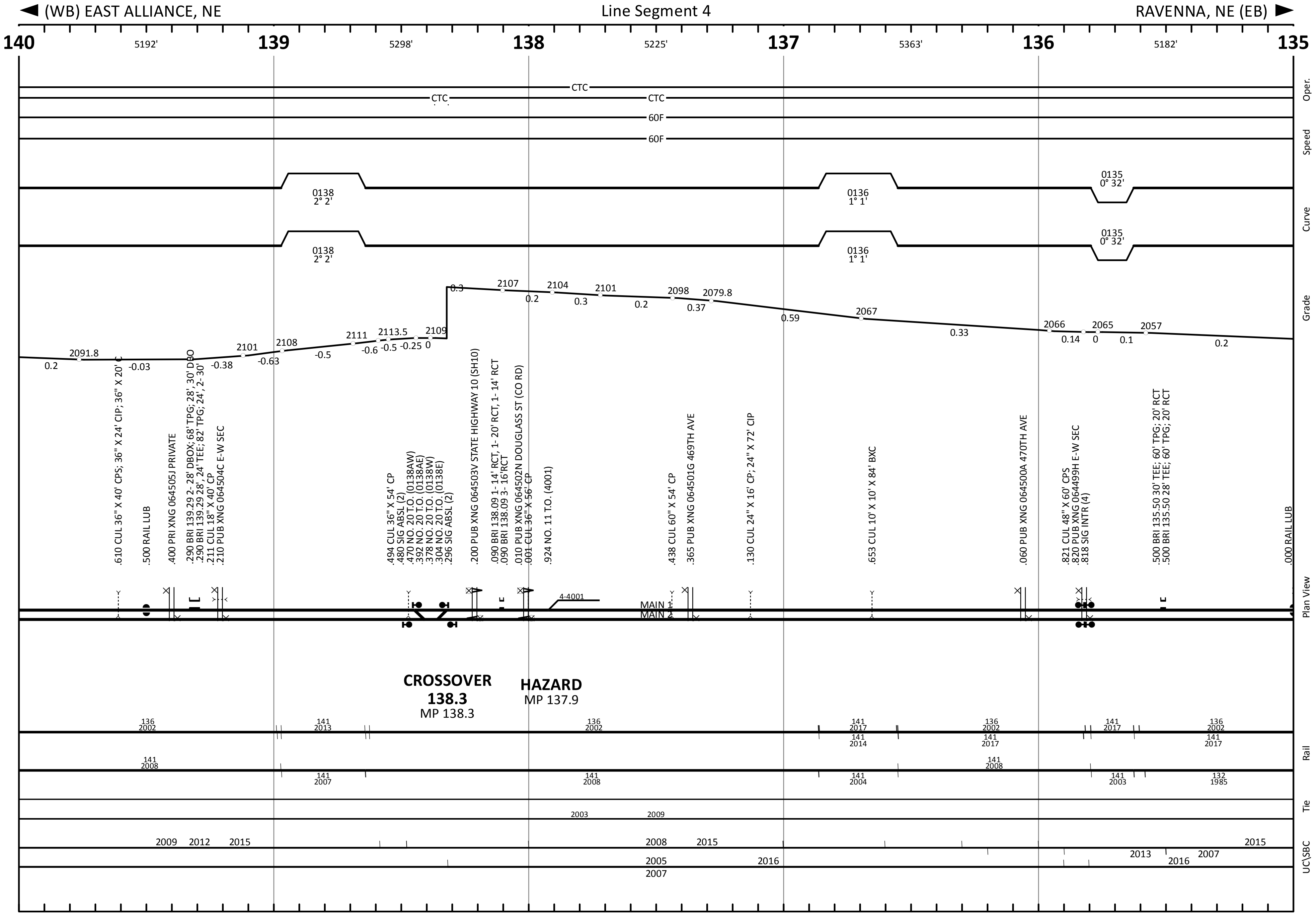
BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: LICTNE
FSAC: 30143
REVISED: 4/25/2016
TEAM: LITC41063.DGN
TRK CHT: SAN057.DGN
TEAM PG 063



System Maintenance and Planning

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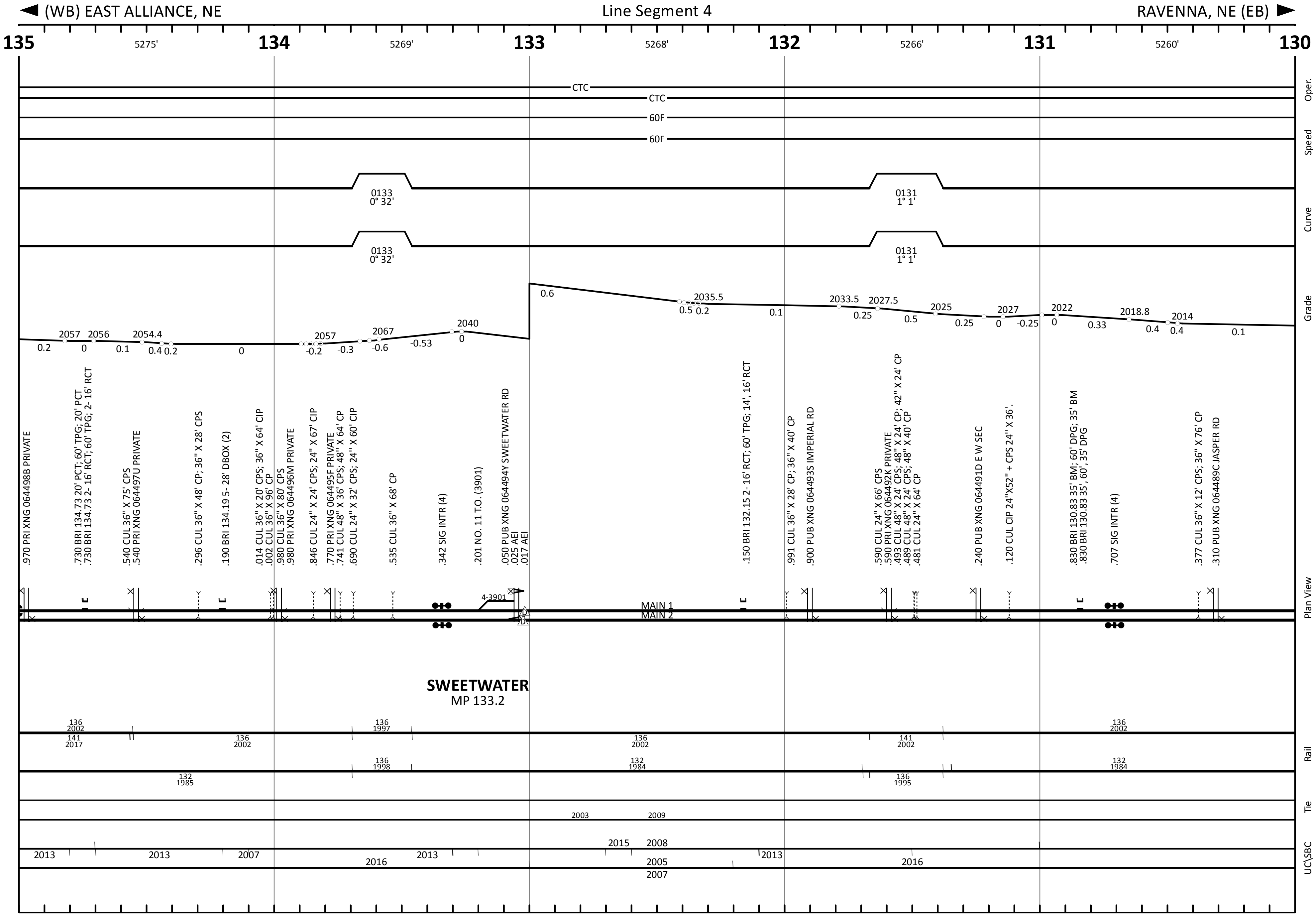

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Sand Hills Subdivision

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Revised to July 16, 2018

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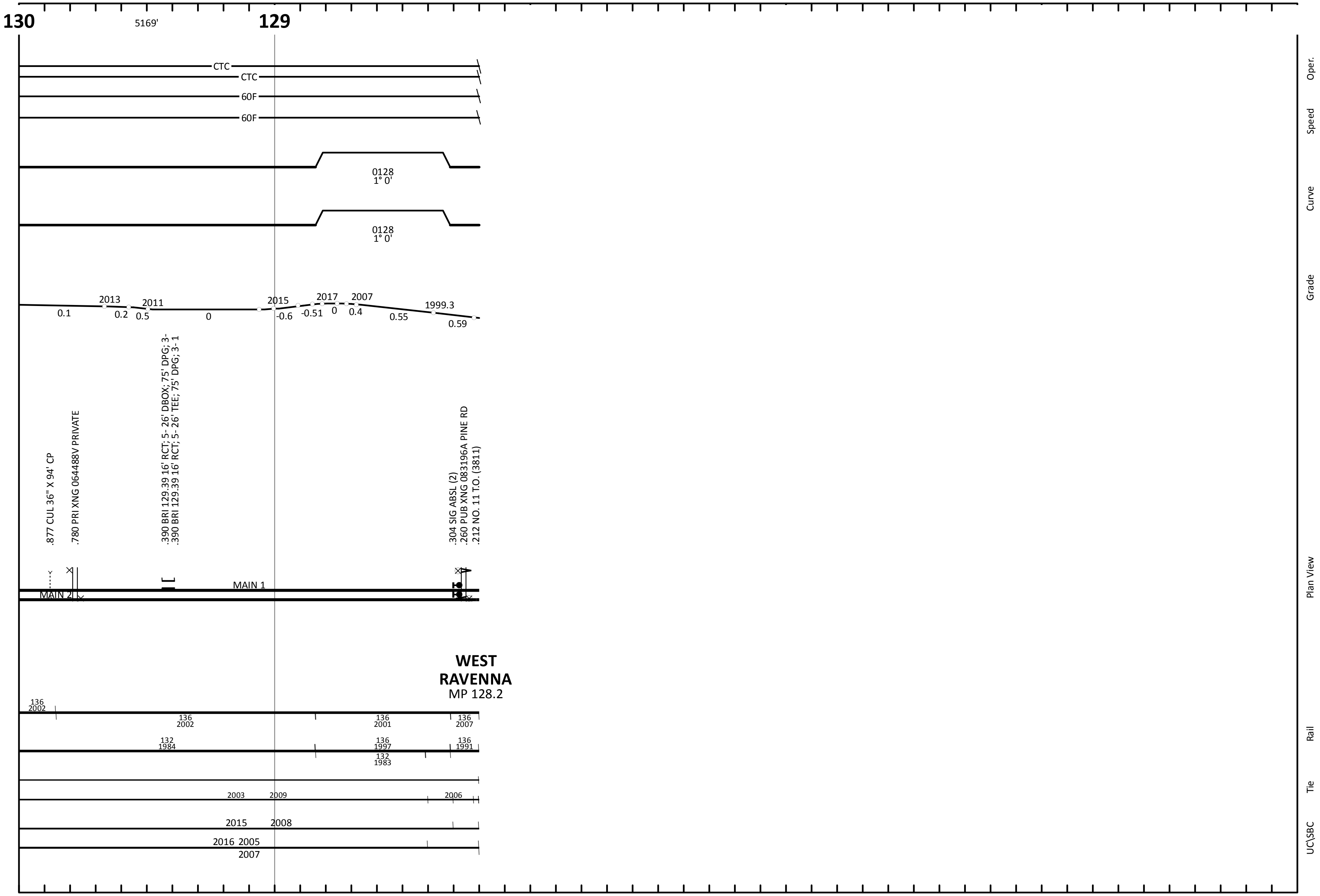

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System Maintenance and Planning

Sand Hills Subdivision

Powder River Operating Division
Powder River East Engineering Division

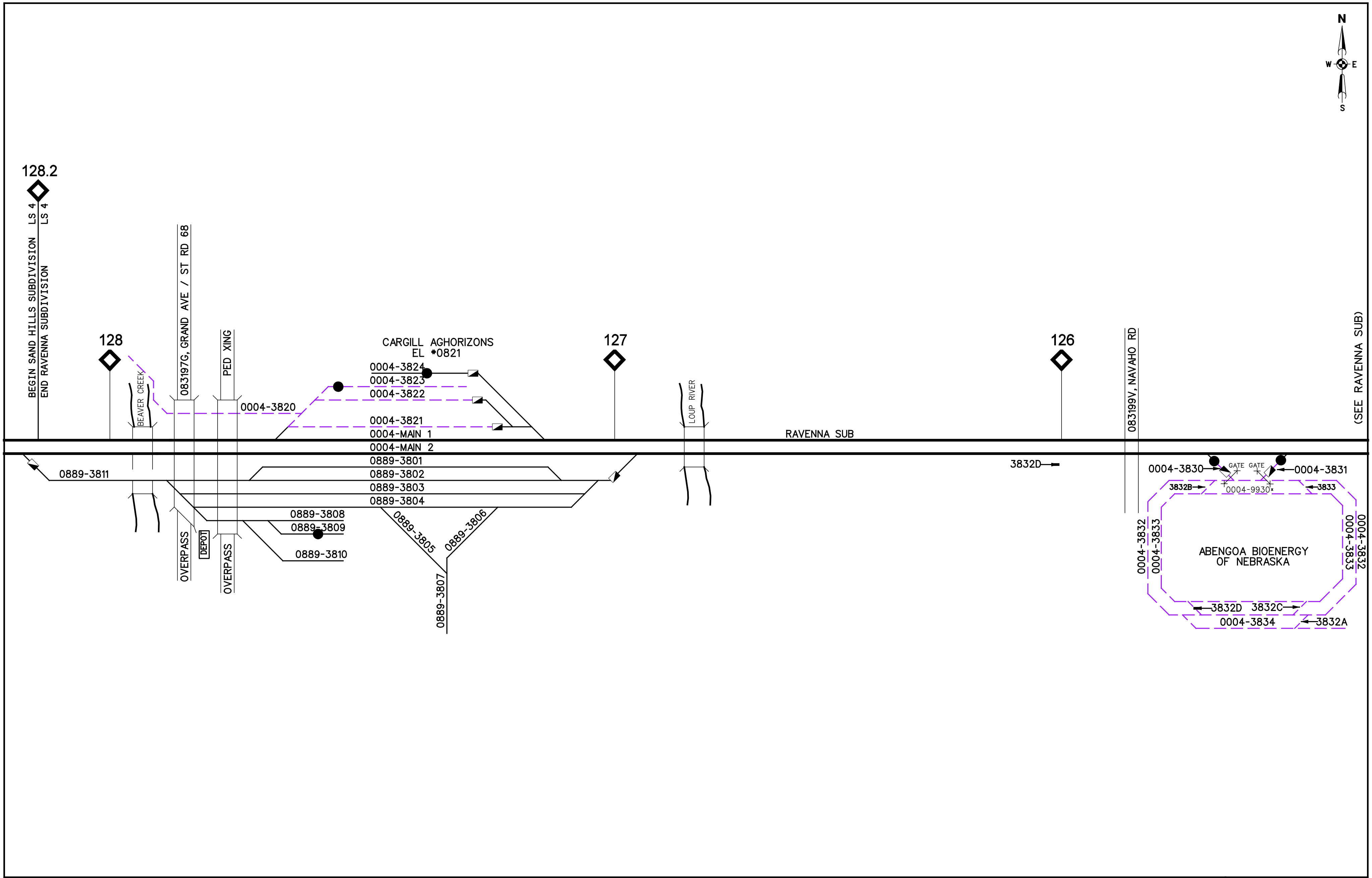
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 16, 2018 Page 60 of 61

RAVENNA, NE
Sand Hills Subdivision

← East Alliance, NE

Hobson, NE →



BNSF
RAILWAY

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◪ DERAIL
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: RAVENN
FSAC: 30126
REVISED: 4/7/2016
TEAM: RAVE38069.DGN
TRK CHT: SAM061.DGN

Track Chart
Valley Subdivision

Northport, NE to East Guernsey, WY

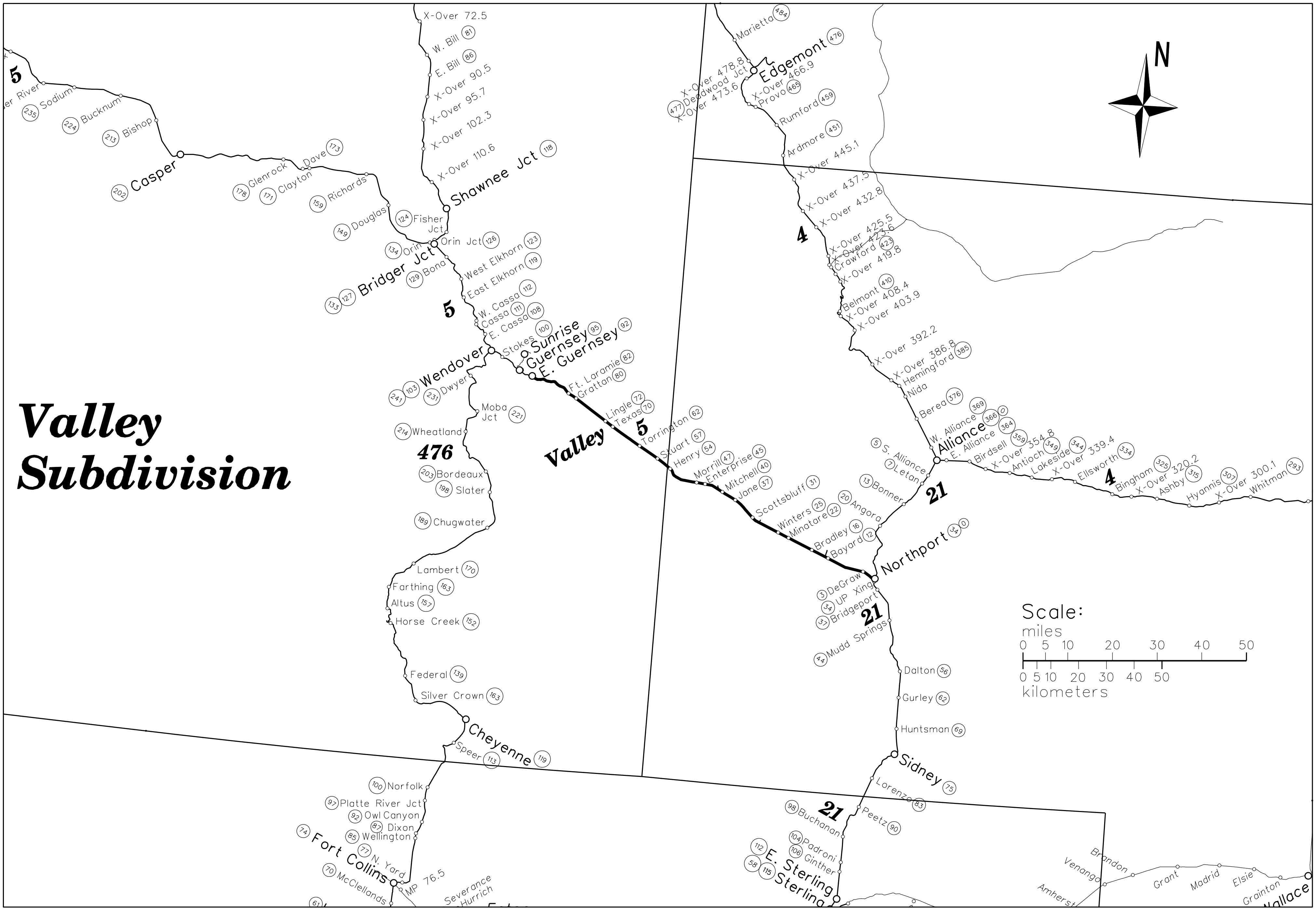
MP 0.0 to MP 90.4

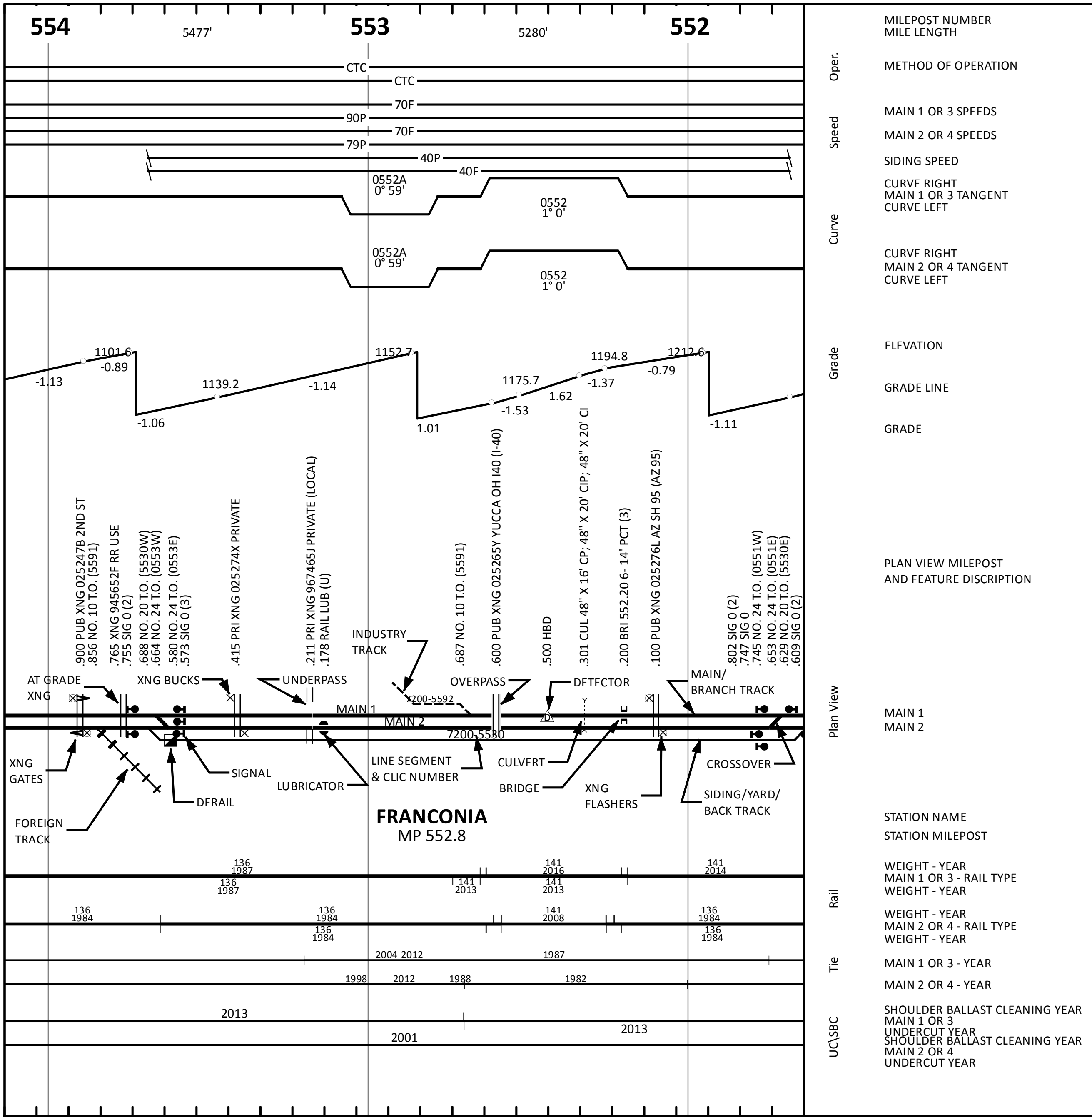
See each page for latest revised date.

Forward all corrections and changes to
BNSF Outlook address
ENGR DL TRACK CHARTS
Or
FAX to (913)-551-4285

BNSF System Maintenance and Planning

Valley Subdivision





TRACK CHART FEATURE LEGEND

NOTES

BRIDGES

THE MILEPOST LOCATION OF A BRIDGE IS THE LOW MILEPOST END OF THE BRIDGE.

CURVES

TRACK SIDE (LEFT OR RIGHT) FOR CURVE IS ACCORDING TO INC MP DIRECTION.

GRADE

GRADE IS SHOWN PERIODICALLY WHERE THE GRADE CHANGES ARE TOO NUMEROUS OVER SHORT DISTANCES TO CLEARLY SHOW.

MILEPOST

ALPHA CHARACTER MILEPOST INDICATE DUPLICATION OF NUMBERS WITHIN A SUB OR MAIN 1 HAS DIFFERENT ALIGNMENT THAN MAIN 2.

TRACK

MAIN LINES ARE SHOWN WITH A BOLD LINE.
TRACK NUMBERS MAY NOT BE AVAILABLE FOR ALL TRACKS.
TRACK NUMBERS MARKED WITH AN * ARE UNKNOWN.

RAIL

WELDED RAIL IS SHOWN WITH A BOLD LINE. BOLTED RAIL IS SHOWN WITH A THIN LINE.

TIES

CONCRETE TIES ARE SHOWN WITH A BOLD LINE. TIMBER TIES ARE SHOWN WITH A THIN LINE.

SCALE

HORIZONTAL: 2"=1 MILE (1 MILE MAY NOT EQUAL 5280') VERTICAL: NONE

DETAIL PAGES

DETAIL SCHEMATIC (TEAM) PAGES CONTAIN SEPARATE LEGEND. REFER TO THOSE PAGES FOR APPLICABLE LEGEND DEFINITIONS.

FILE: Y:\drawings\trkchrts\ASTC\MXD_Files\TC_Legend.mxd

Track Chart Abbreviations

Track and Signal

ABD	ACOUSTIC BEARING DETECTOR
ABS	AUTOMATIC BLOCK SIGNAL SYSTEM
AEI	AUTOMATIC EQUIPMENT IDENTIFICATION DETECTOR
ATS	AUTOMATIC TRAIN STOPS
BFD	BROKEN FLANGE DETECTOR
BR SIG	BRIDGE SIGNAL
CANT SIG	CANTILEVER SIGNAL
CTC	CENTRALIZED TRAFFIC CONTROL
DED	DRAGGING EQUIPMENT DETECTOR
DESLTD	DRAGGING EQUIP. & SHIFTED LOAD W/ TOP DETECTOR
F	FREIGHT (SPEED)
F/G	FLASHING SIGNAL WITH AUTOMATIC GATES
FL	FLASHING SIGNAL
HBD	HOT BEARING DETECTOR
HWD	HIGH WATER DETECTOR
I TOWER	INTERLOCKING TOWER
INTLK	INTERLOCKING
LS	LINE SEGMENT
MP	MILEPOST
NO	NUMBER
OCS	OCCUPANCY CONTROL SYSTEM
OH	OVERHEAD
OOS	OUT OF SERVICE
P	PASSENGER (SPEED)
RES LIM	RESTRICTED LIMITS
RL	RAIL LUBRICATOR
S SW	SPRING SWITCH
SBC	SHOULDER BALLAST CLEANING
SIGS	SIGNALS
SLD	SHIFTED LOAD DETECTOR
SLTD	SHIFTED LOAD WITH TOP DETECTOR
TO	TURNOUT
TRK	TRACK
TWC	TRACK WARRANT CONTROL
UC	UNDERCUT
WILD	WHEEL IMPACT LOAD DETECTOR
YL	YARD LIMIT

Miscellaneous

AVE	AVENUE
BLVD	BOULEVARD
CO	COUNTY
CONN	CONNECTION
CONST	CONSTRUCTED
CR	CREEK OR CRUSHED ROCK
DBL	DOUBLE
DIV	DIVISION
DR	DRIVE
E	EAST
EL	ELEVATION
F LT P	FLOOD LIGHT POLE
F LT T	FLOOD LIGHT TOWER
FRT	FREIGHT
GR	AT GRADE
HO	HOUSE
HWY	HIGHWAY
IND	INDUSTRY
JCT	JUNCTION
JT	JOINT
LT	LEFT
MAX	MAXIMUM
MIN	MINIMUM
MTCE	MAINTENANCE
NO	NORTH
OH	OVERHEAD
OP	OVERPASS
PED	PEDESTRIAN
PK	PARKWAY
PO	POWER
PSGR	PASSENGER
PUB	PUBLIC
PVT	PRIVATE
RD	ROAD
RIV	RIVER
RR	RAILROAD
RT	RIGHT
RW	RIGHT OF WAY
RY	RAILWAY
SEC	SECTION
SO	SOUTH
ST	STREET
STA	STATION
SUB	SUBDIVISION
TPL	TRIPLE
UP	UNDERPASS
W	WEST
XBUCKS	CROSSBUCKS
XING	CROSSING
YD	YARD

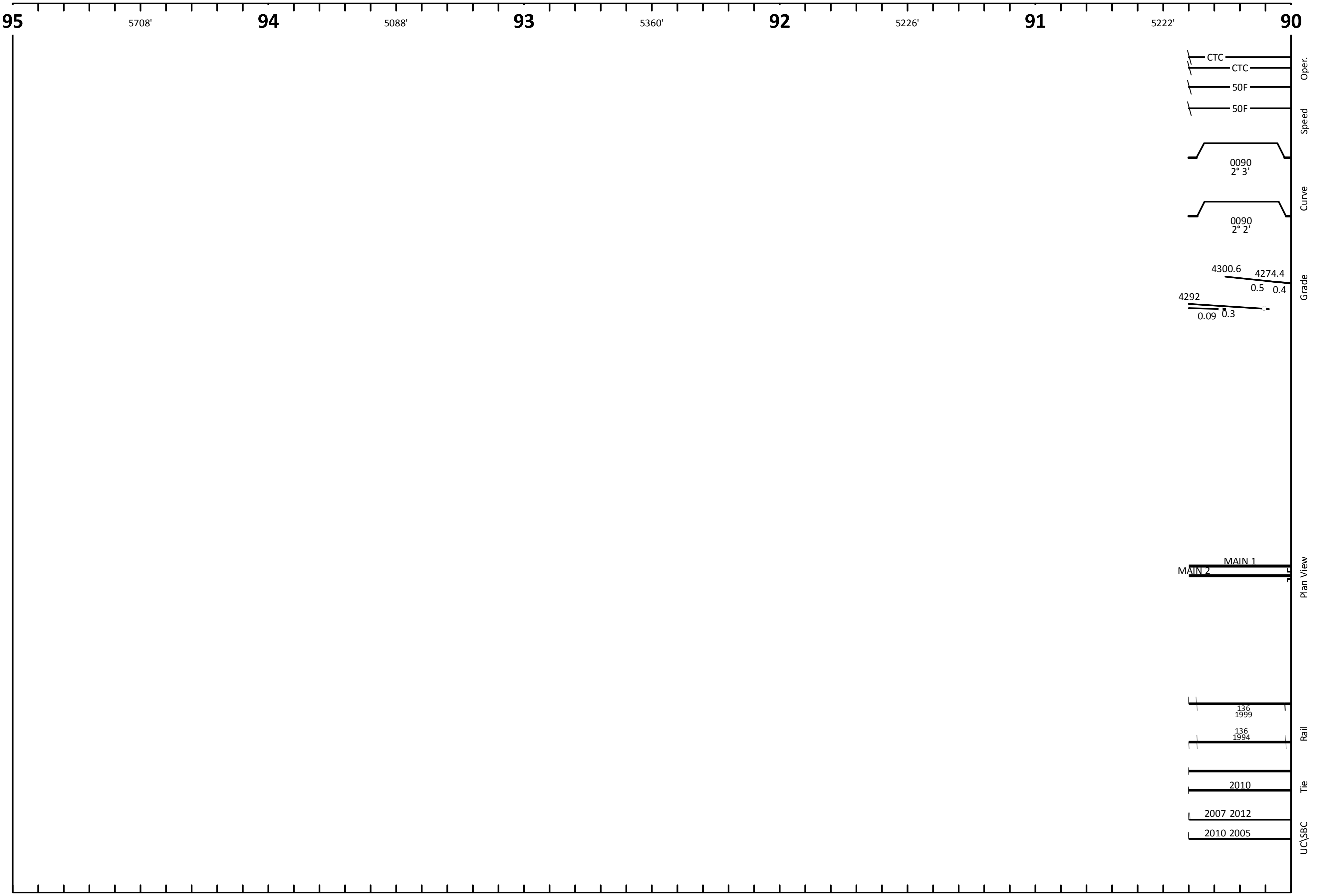
Bridges

BASC	BASCULE
BD	BALLAST DECK
BDPT	BALLAST DECK PILE TRESTLE - TIMBER
BM	BEAM SPAN
BPT	BALLAST DECK TIMBER TRESTLE
BR	BRIDGE
CA	CONCRETE ARCH
CEBM	BEAM SPAN CONCRETE ENCASED
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CUL	CULVERT
DBOX	PRESTRESSED DOUBLE CELL CONCRETE BOX GIRDER
DBXS	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER, SLOPED CURBS
DPCT	DECK PLATE CONNECTED TRUSS
DPCT	DECK TRUSS PIN CONNECTED
DPG	DECK PLATE GIRDER
DPLG	DECK PLATE LATTICE GIRDER
DRT	DECK RIVETED TRUSS
DS	SWING SPAN
EGIR	MISC. POST-TENSIONED CONCRETE GIRDER
EXT	EXTENSION
LS	LIFT SPAN
MA	MASONRY ARCH
MGIR	MISC. CONCRETE GIRDER
OD	OPEN DECK
OPT	OPEN DECK TIMBER TRESTLE
PCT	PRESTRESSED CONCRETE TRESTLE SLAB
PGIR	PRESTRESSED MISC. CONCRETE GIRDER
PPCT	PONY TRUSS PIN CONNECTED
PRT	PONY RIVETED TRUSS
PTT	PONY TRUSS TIMBER
RAIL	RAIL STRINGER
RCT	REINFORCED CONCRETE TRESTLE
SA	STEEL ARCH
SBG	STEEL BOX GIRDER
SBOX	PRESTRESSED SINGLE CELL CONCRETE BEAM OR GIRDER
SGIR	MISC. STEEL GIRDER
STEE	PRESTRESSED THRU VOIDED CONCRETE SUPER TEE GIRDER
TDBX	THRU VOID, DBL CELL PRES. CONC. BEAM OR GIRDER
TDBX	PRESTRESSED THRU VOID, DBL. CELL, CONC. BOX GIRDER
TEE	PRESTRESSED CONCRETE TEE GIRDER
THT	THRU TIMBER TRUSS
TIM	MISC. TIMBER SPAN
TPCT	THRU PLATE CONNECTED TRUSS
TPG	THRU PLATE GIRDER
TPLG	THRU PLATE LATTICE GIRDER
TRT	THRU RIVETED TRUSS
TSBX	PRESTRESSED THRU VOID, SINGLE CELL, CONC. BEAM OR GIRDER
VTEE	PRESTRESSED THRU VOIDED CONCRETE TEE GIRDER

Culverts

BXC	CONCRETE BOX
BXC2	CONCRETE DOUBLE BOX
BXC3	CONCRETE TRIPLE BOX
BXCM	CONCRETE MULTI-OPENING BOX
BXM	MASONRY BOX
BXM2	MASONRY DOUBLE BOX
BXMM	MASONRY MULTI-OPENING BOX
BXT	TIMBER BOX
BXT2	TIMBER DOUBLE BOX
BXTM	TIMBER MULTI-OPENING BOX
CAPA	CORRUGATED ARCH PIPE, ALUMINUM
CAPS	CORRUGATED ARCH PIPE, STEEL
CIP	CAST IRON PIPE
CP	CONCRETE PIPE
CPA	CORRUGATED PIPE, ALUMINUM
CPP	CORRUGATED PIPE, PLASTIC
CPS	CORRUGATED PIPE, STEEL
EPC	ELLIPTICAL PIPE, CONCRETE
MP	MASONRY PIPE
PAC	CONCRETE ARCH PIPE
PL	CLAY TILE PIPE
PP	PLASTIC PIPE, SMOOTH WALL
PS	STEEL PIPE, SMOOTH WALL
PSAP	STRUCTURAL STEEL ARCH PLATE PIPE
PSP	STRUCTURAL STEEL PLATE PIPE
PV	VITREOUS PIPE, SMOOTH WALL

◄ (WB) East Guernsey, WY Line Segment 5 Northport, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

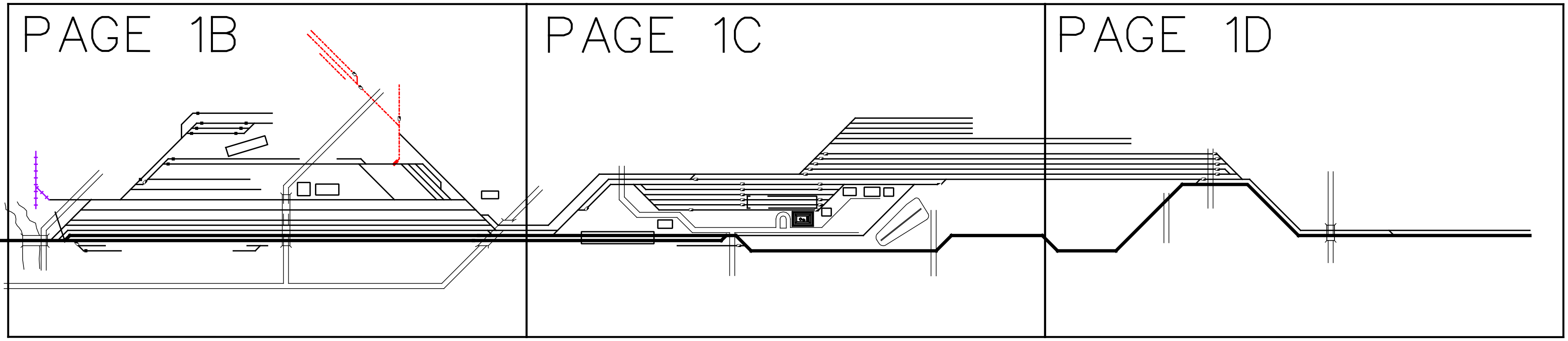
Updates: ENGRMASTERDATAMGMT@bnsf.com

GUERNSEY, WY

Valley Subdivision

← East Guernsey, WY

Northport, NE →



BNSF RAILWAY

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BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

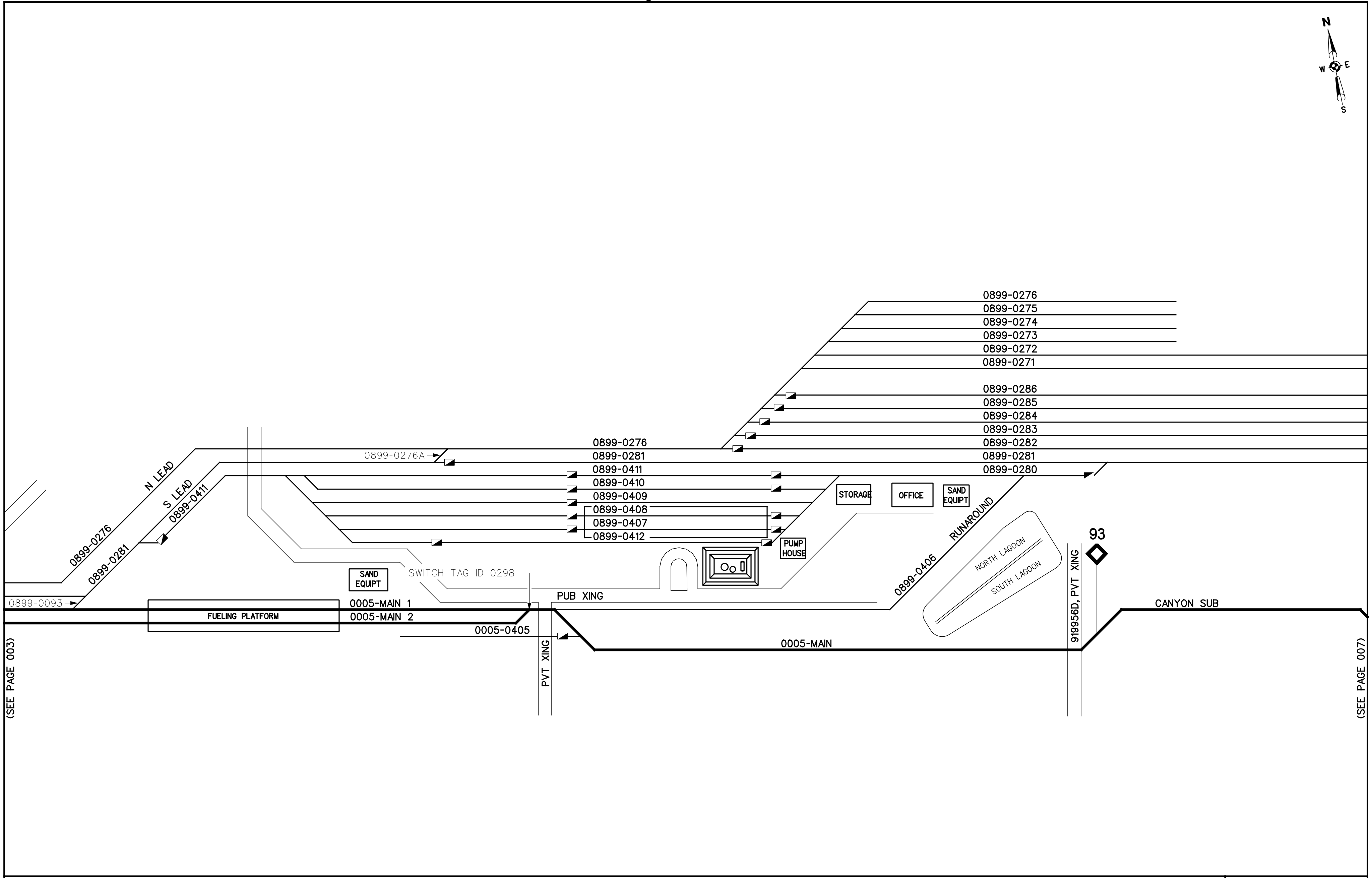
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: GUERWY
FSAC: 32129
REVISED: 9/20/2013
TEAM: *********.DGN
TRK CHT: VAL001A.DGN
TEAM PG ###

GUERNSEY, WY
Valley Subdivision

← Bridger Jct., WY

Northport, NE →



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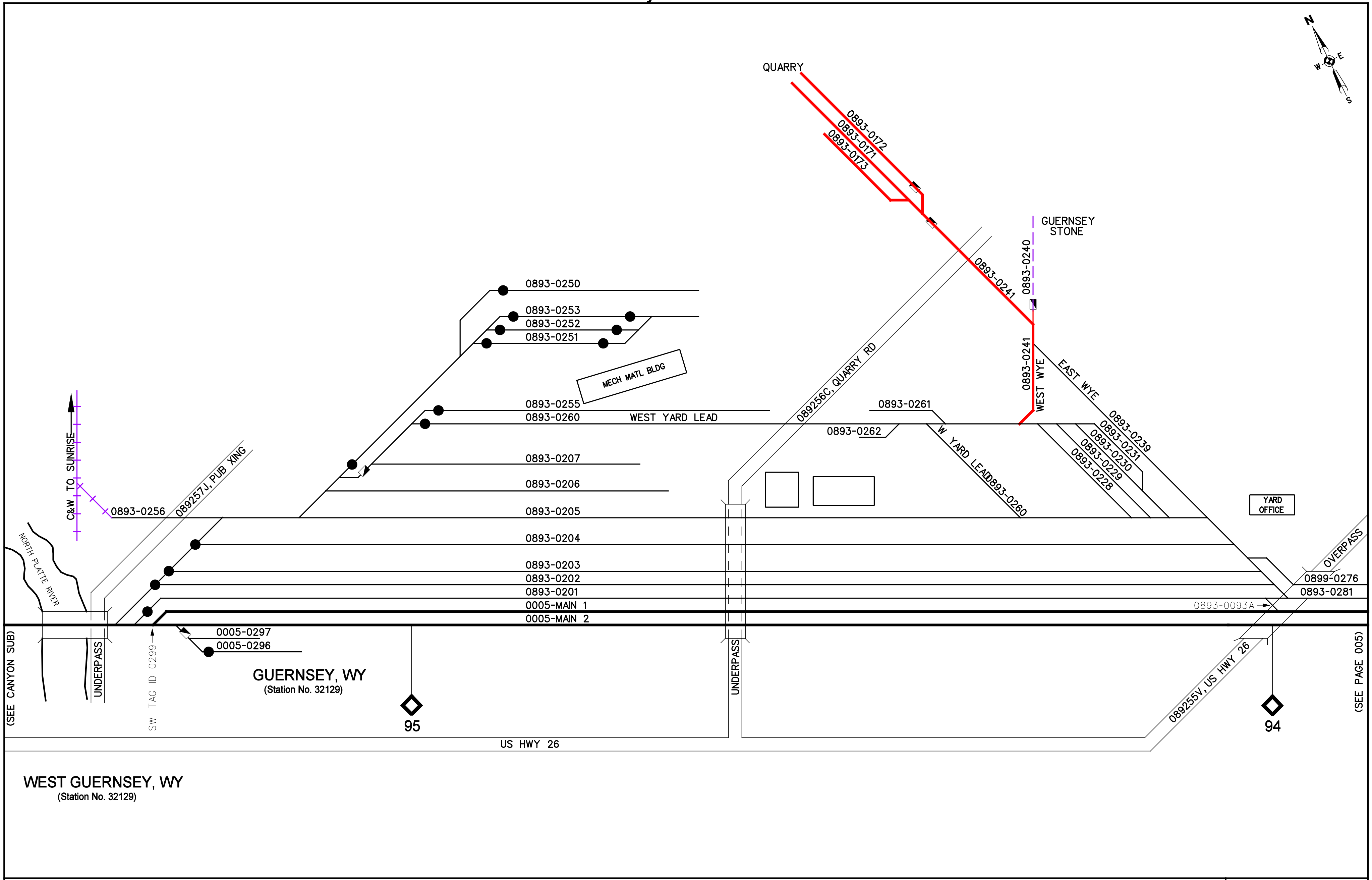
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: GUERWY
FSAC: 32129
REVISED: 1/15/2014
TEAM: GUER02005.DGN
TRK CHT: VAL001C.DGN

GUERNSEY, WY
Valley Subdivision

◄— Bridger Jct., WY

Northport, NE —►



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●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪	DERAIL
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———	TRACKAGE RIGHTS
—┼┼—┼┼—	FOREIGN TRACK

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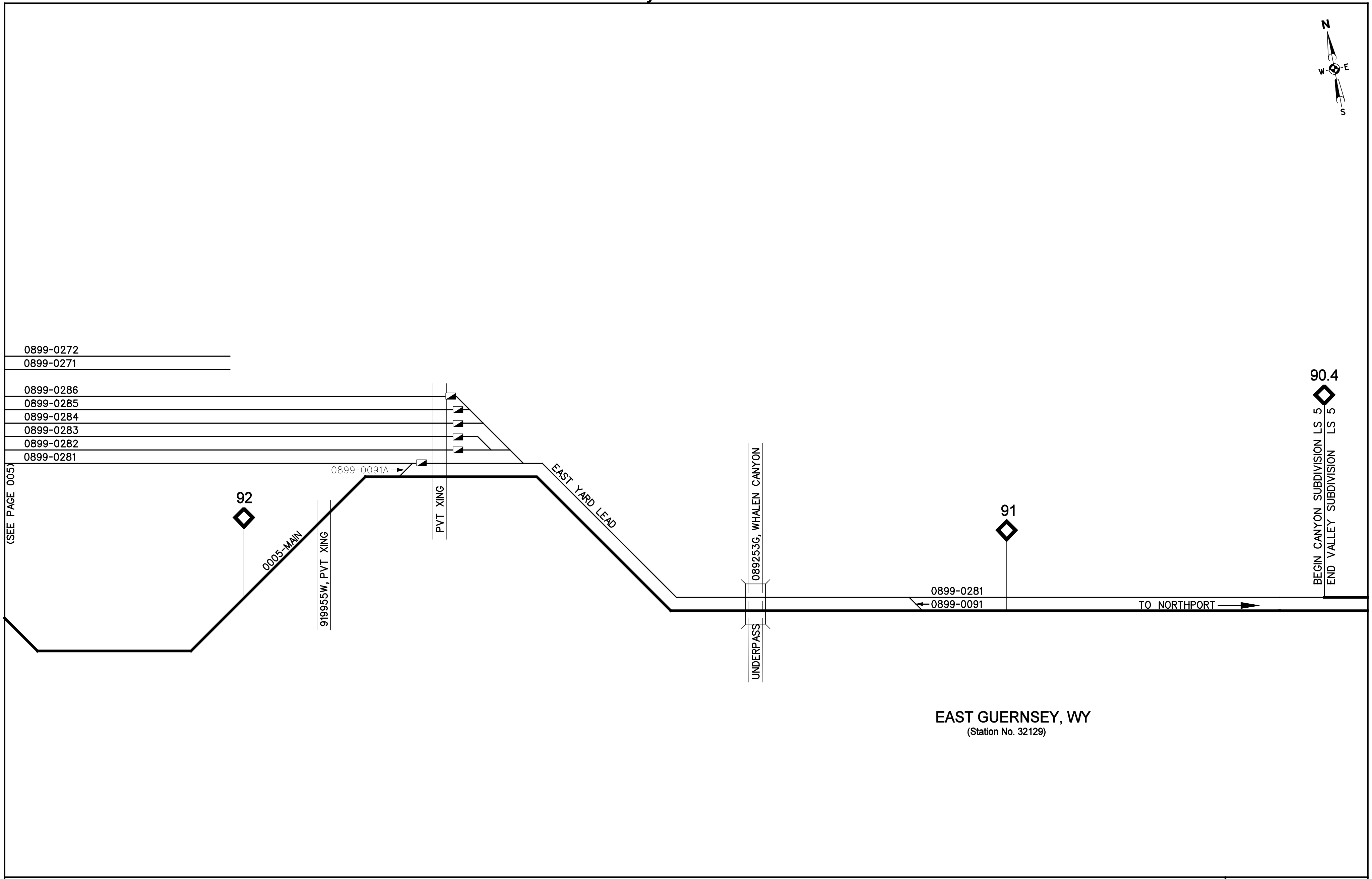
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: GUERWY
FSAC: 32129
REVISED: 11/18/2016
TEAM: GUER01003.DGN
TRK CHT: VAL008.DGN
TEAM PG 003

GUERNSEY, WY
Valley Subdivision

← Bridger Jct., WY

Northport, NE →



EAST GUERNSEY, WY
(Station No. 32129)

BNSF
RAILWAY

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—◆—◆—	INDUSTRY OWNED & BNSF MAINT	▬▬▬	TRACKAGE RIGHTS
— — —	IND OWNED & MAINT	┼─┼─┼	FOREIGN TRACK
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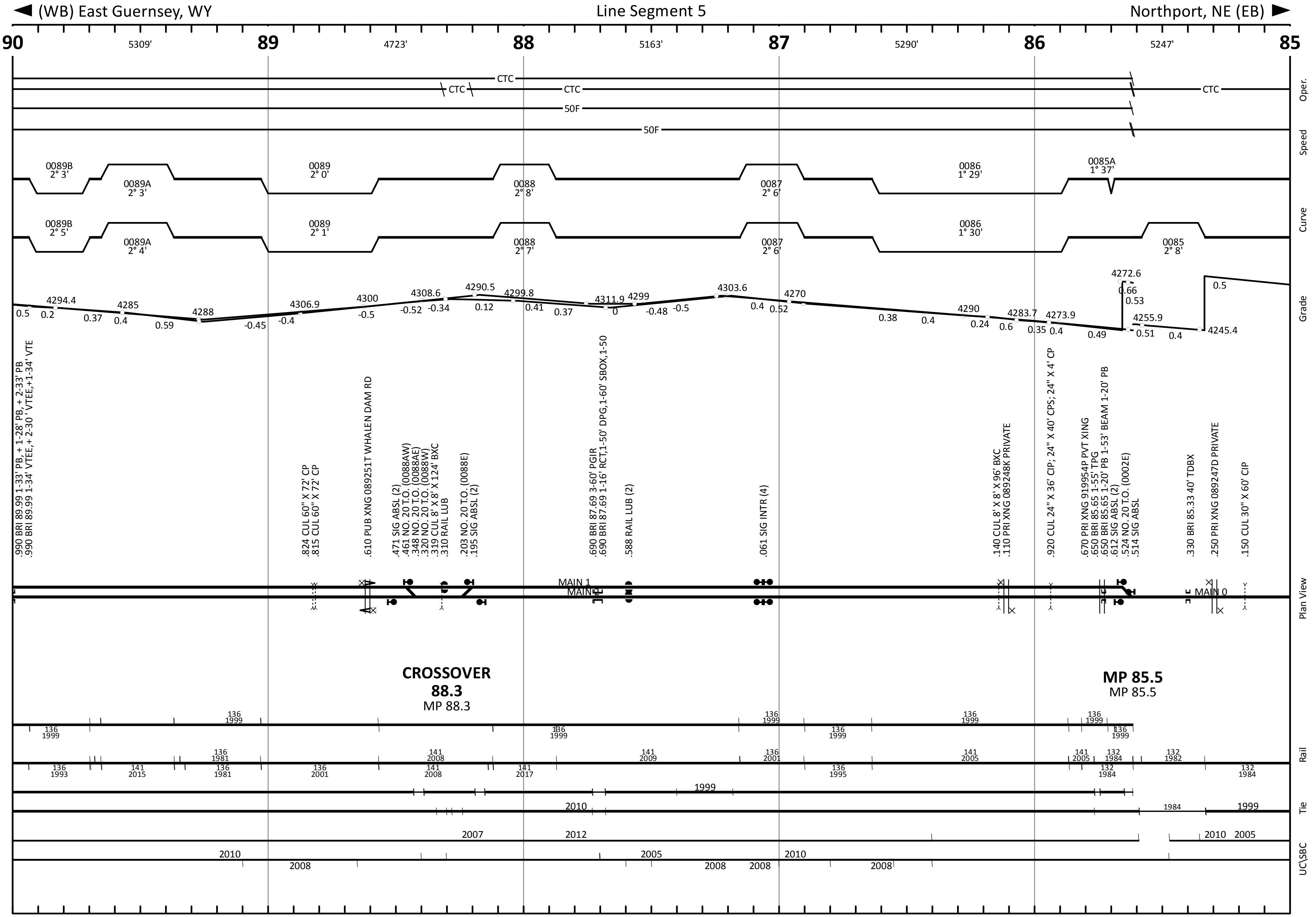
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

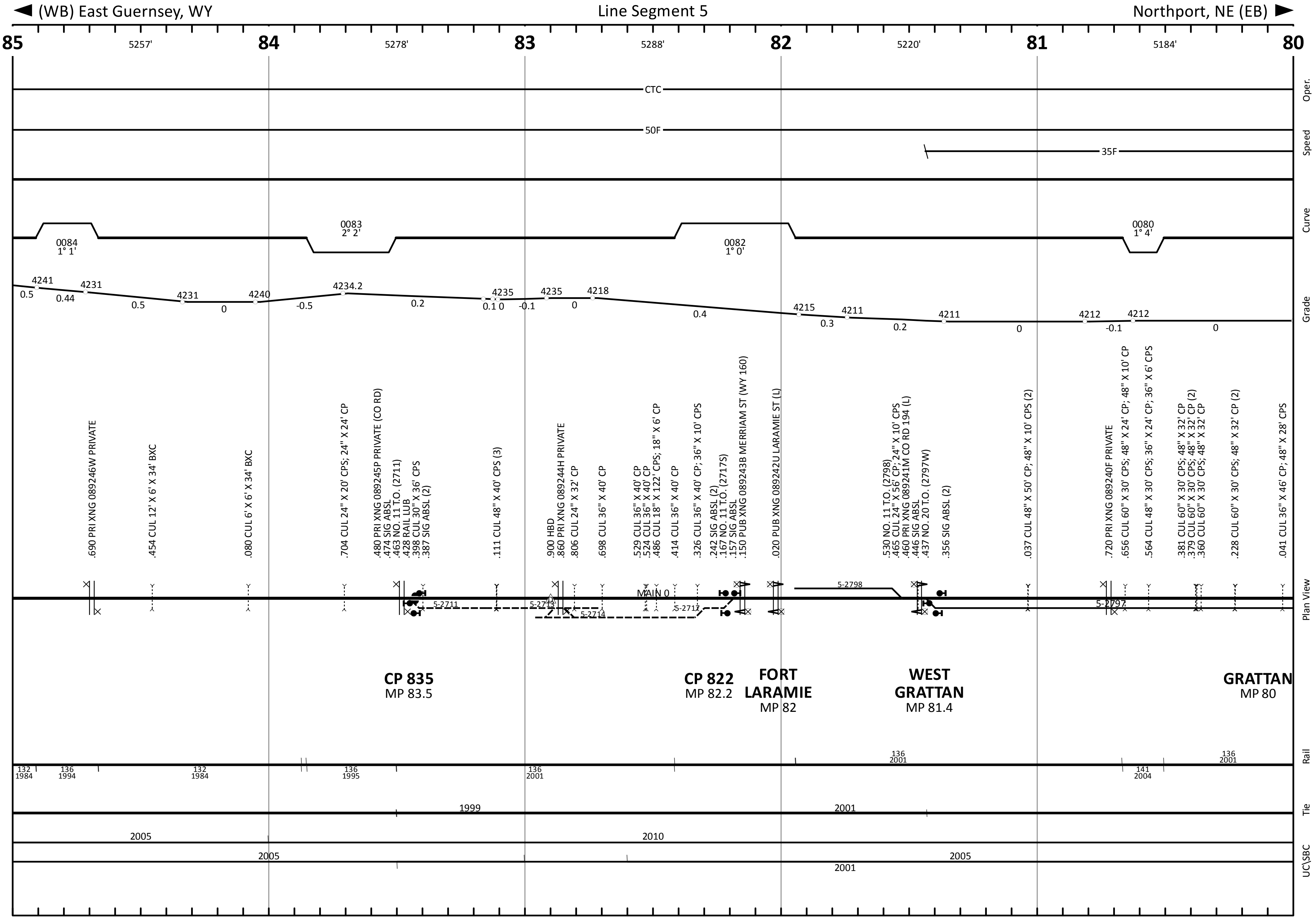
STATION ABBR: GUERWY
FSAC: 32129
REVISED: 1/15/2014
TEAM: GUER02007.DGN
TRK CHT: VAL001D.DGN



BNSF RAILWAY
System Maintenance and Planning

Valley Subdivision
Powder River Operating Division
Powder River North Engineering Division

Engineering Track Chart
Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018 Page 10 of 34



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division
Powder River North Engineering Division

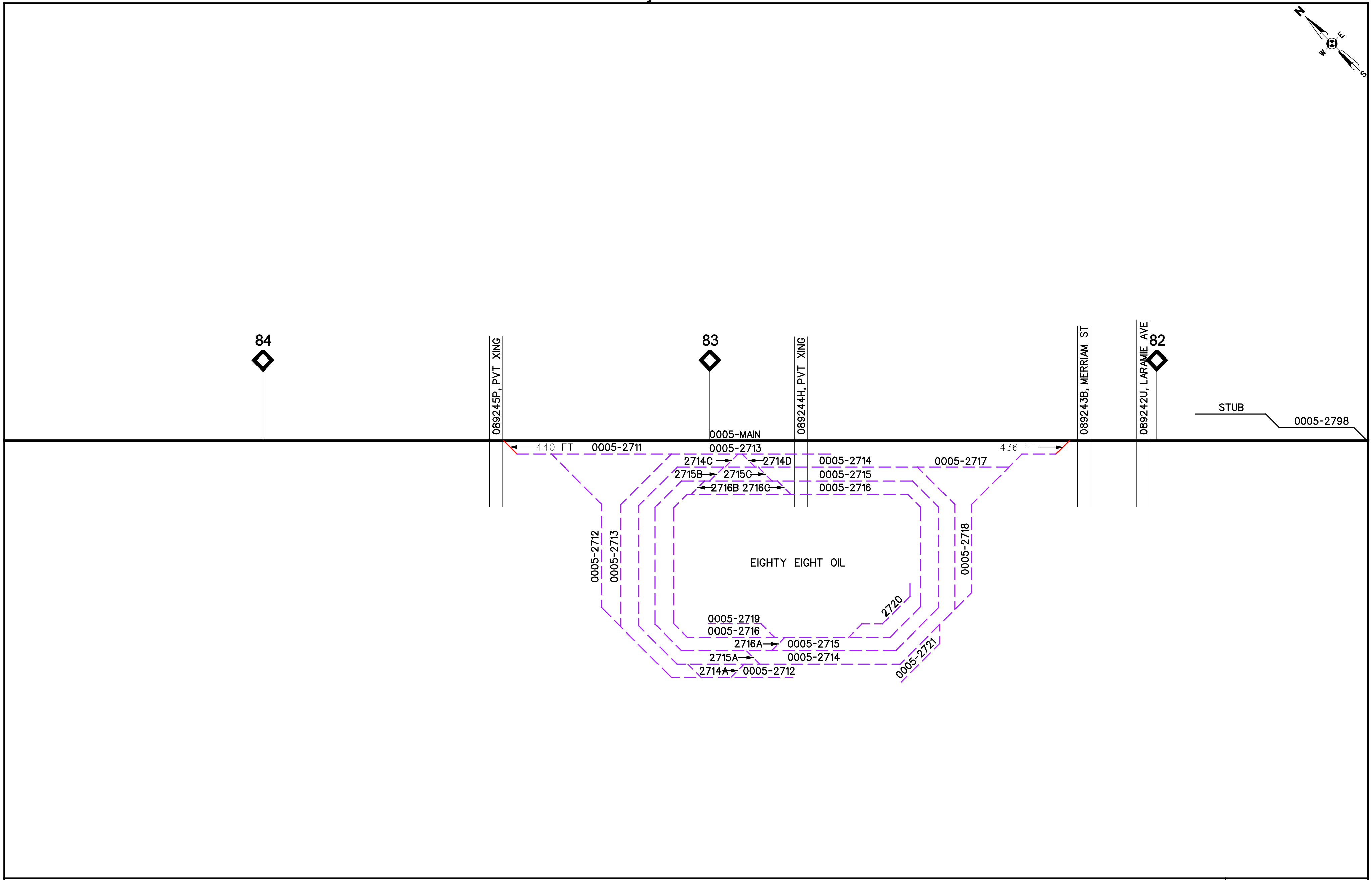
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018

FT. LARAMIE, WY
Valley Subdivision

← East Guernsey., WY

Northport, NE →



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
8 DIGIT NUMBER IS A LINE SEGMENT FOLLOWED BY A CLIC (0001-1234)
* UNKNOWN TRACK NUMBER

REFER TO DIVISION TIMETABLE FOR:
SPECIFIC RADIO FREQUENCIES
SPECIAL CONDITIONS (ITEM #7)
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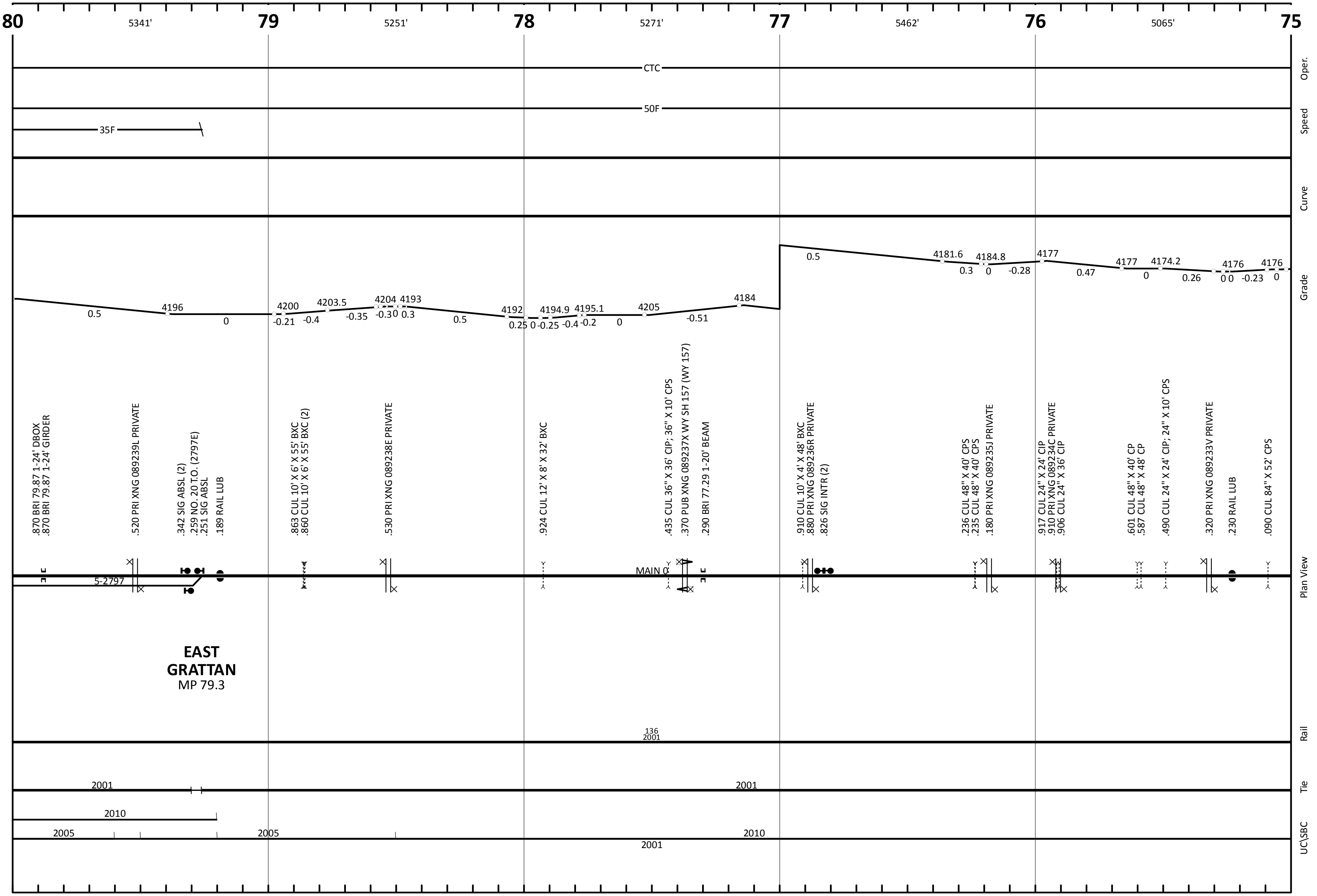
EMPLOYEES MUST BE FAMILIAR AND COMPLY WITH ALL GENERAL NOTICES ON TERRITORY WHICH THEY ARE PERFORMING DUTY

────	BNSF OWNED & MAINT
─◆─◆─	INDUSTRY OWNED & BNSF MAINT
─ ─ ─	IND OWNED & MAINT
●─●─●─●	INDUSTRY MAINT & BNSF OWNED (LEASE)
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪	DERAIL
─┼─┼─	JOINT FACILITIES
────	TRACKAGE RIGHTS
─┼─┼─┼─	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: FTLARA
FSAC: 32116
REVISED: 10/15/2014
TEAM: FTLA27009.DGN
TRK CHT: VAL012.DGN
TEAM PG 009

◄ (WB) East Guernsey, WY Line Segment 5 Northport, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division

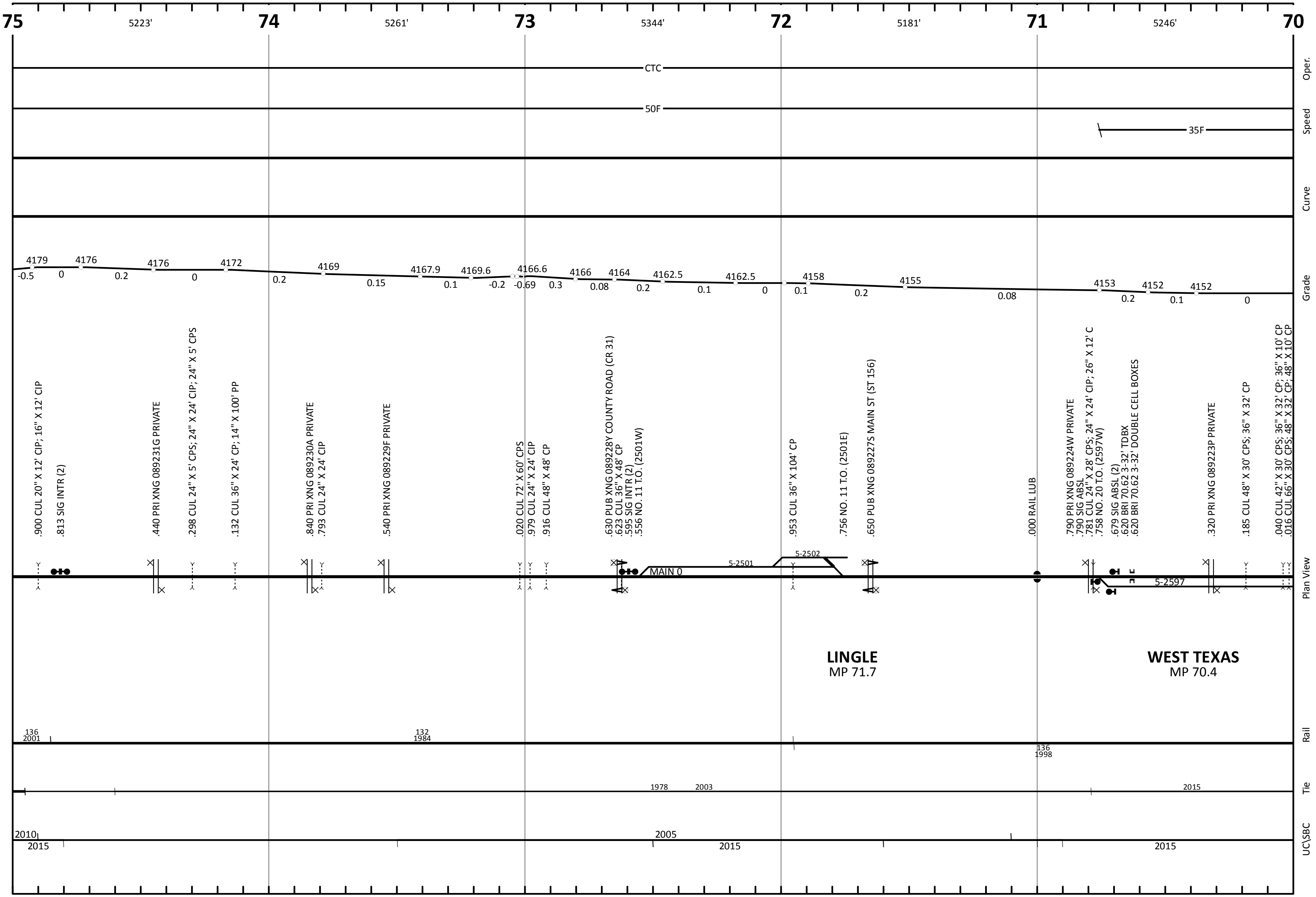
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018

◄ (WB) East Guernsey, WY Line Segment 5 Northport, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

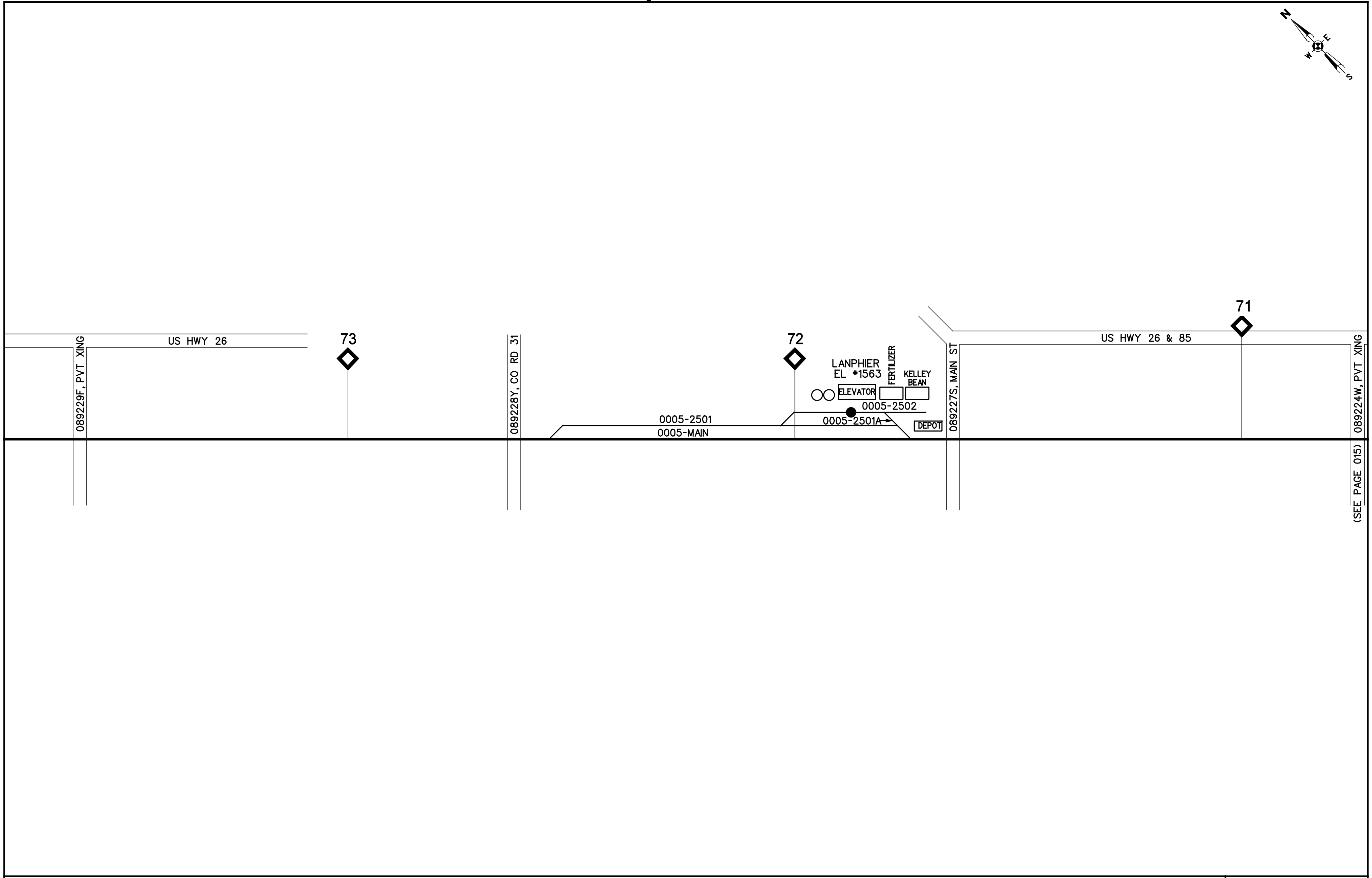
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018

LINGLE, WY
Valley Subdivision

◄— East Guernsey, WY

Northport, NE —►



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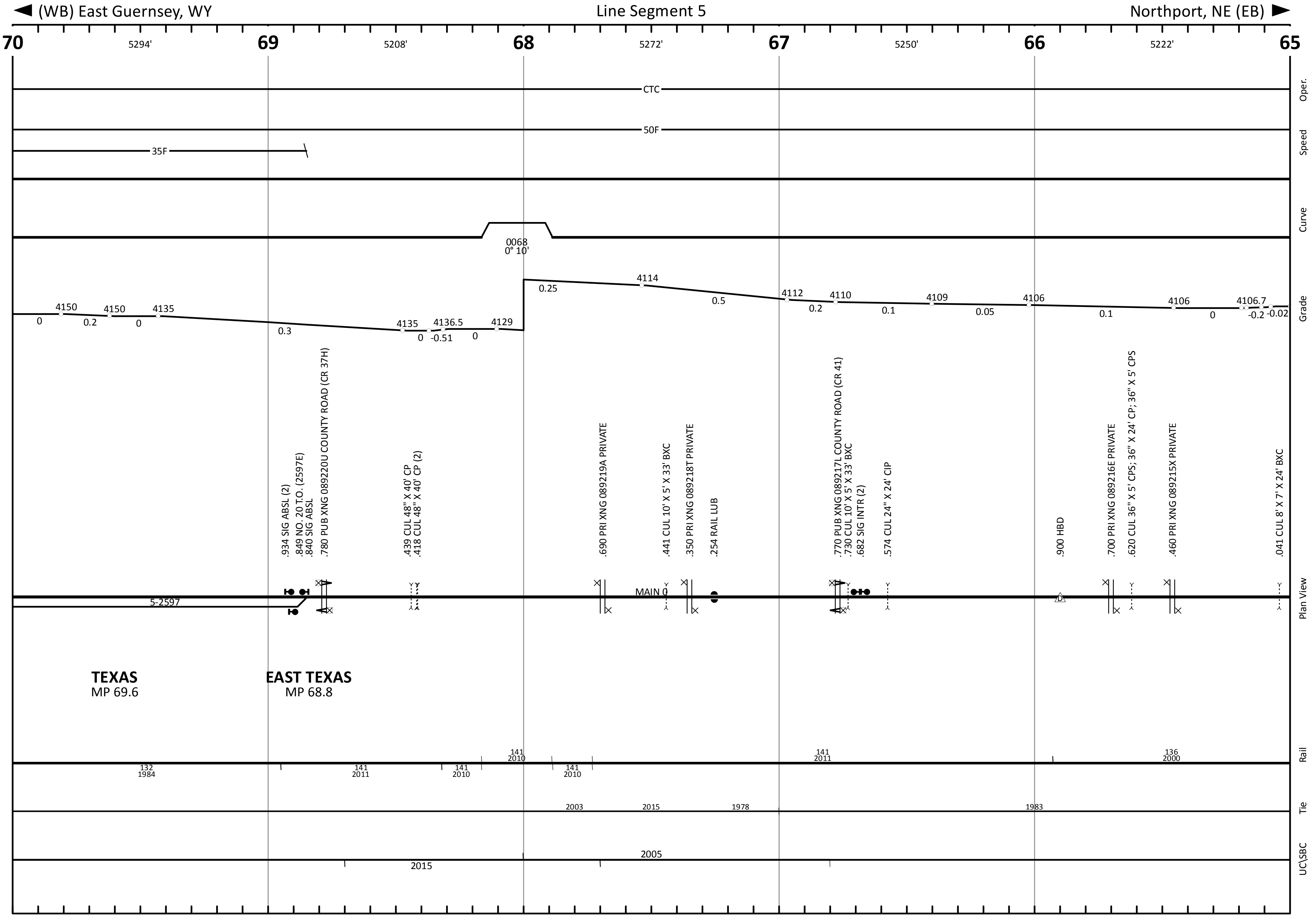
BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: LINGLE
FSAC: 32106
REVISED: 1/16/2014
TEAM: LING25013.DGN
TRK CHT: VAL005A.DGN



BNSF RAILWAY

System Maintenance and Planning

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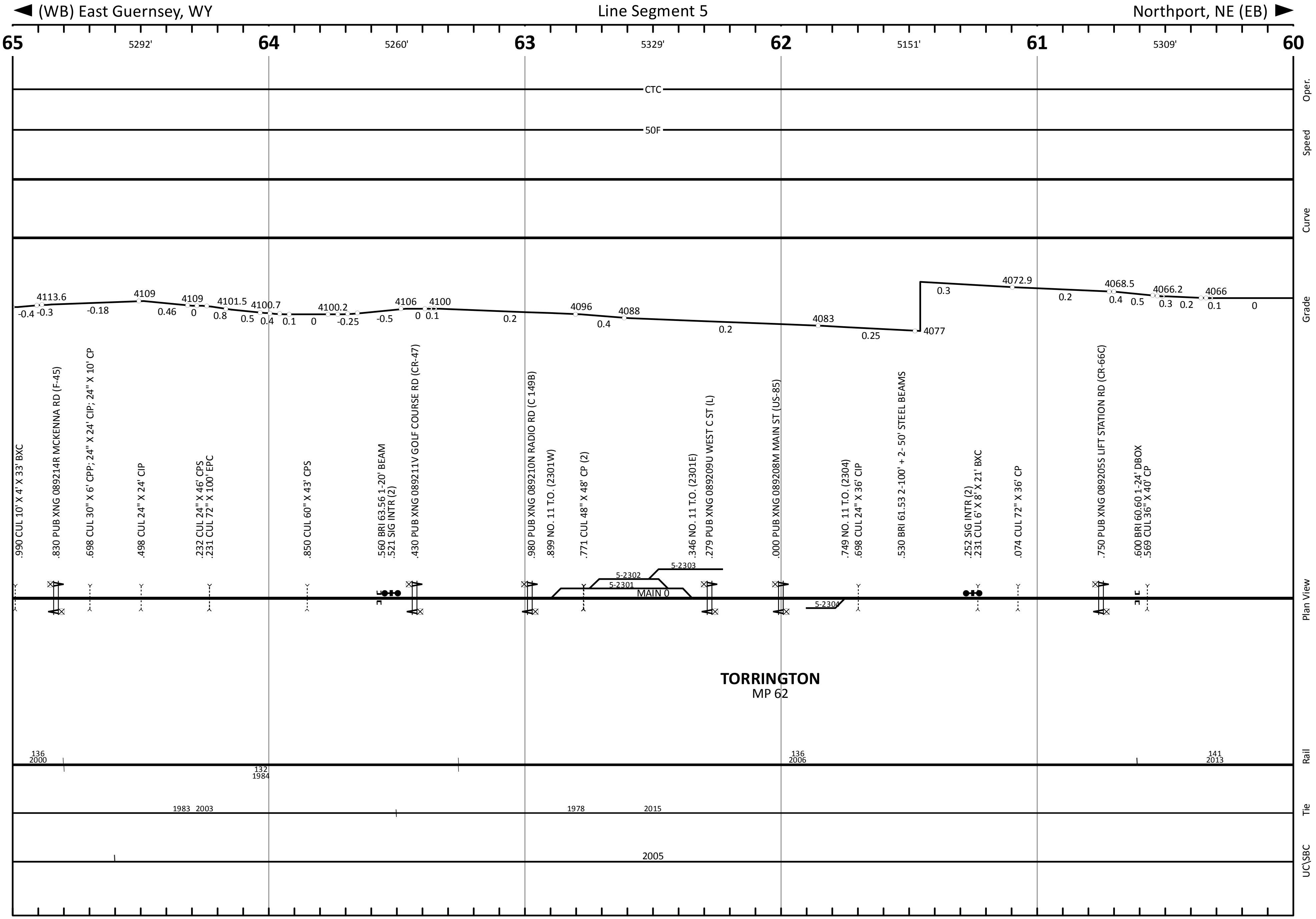
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018



RAILWAY

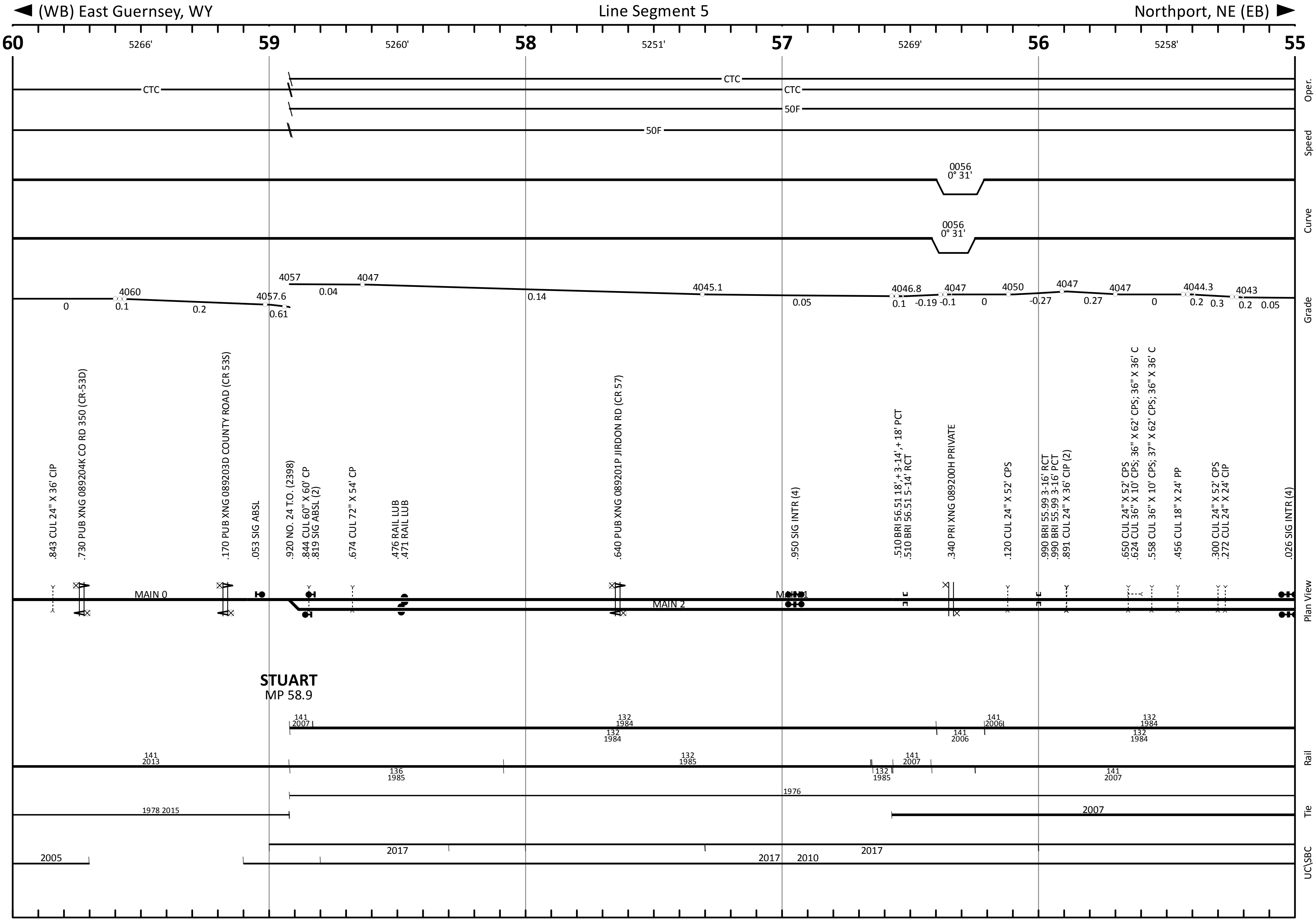
System Maintenance and Planning

Valley Subdivision

Powder River Operating Division
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018 Page 17 of 34



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

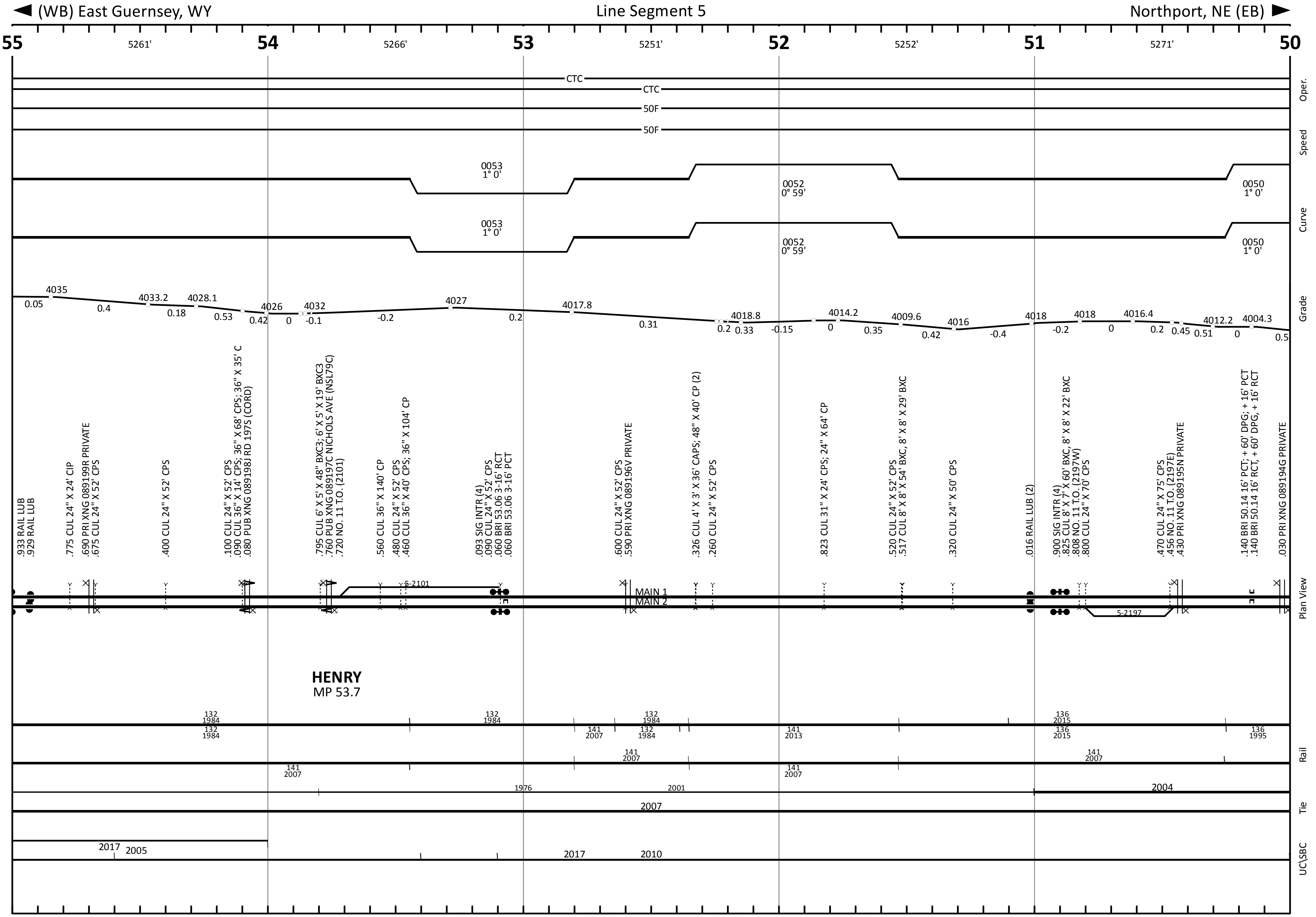
Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018 Page 18 of 34



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

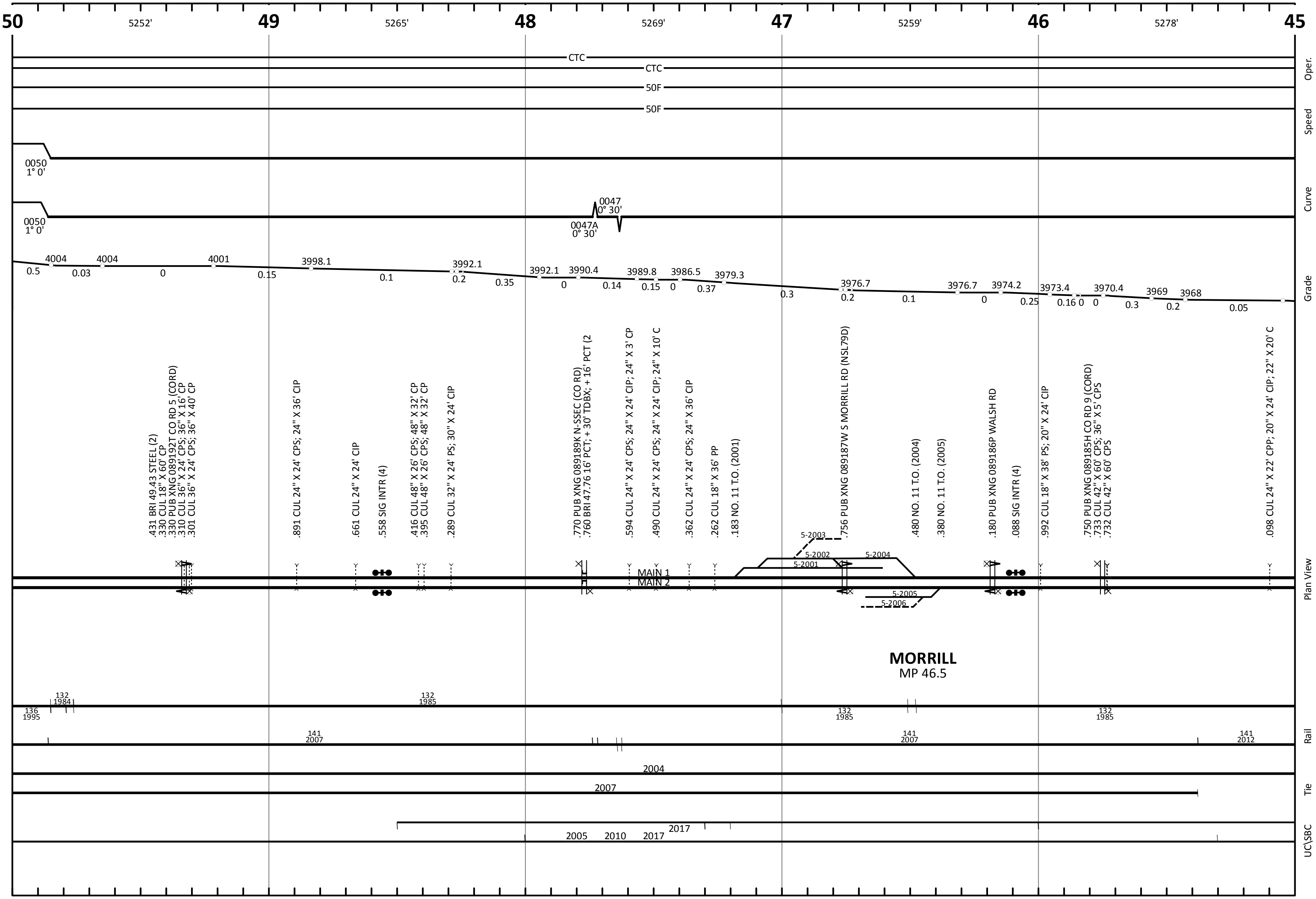
Powder River Operating Division

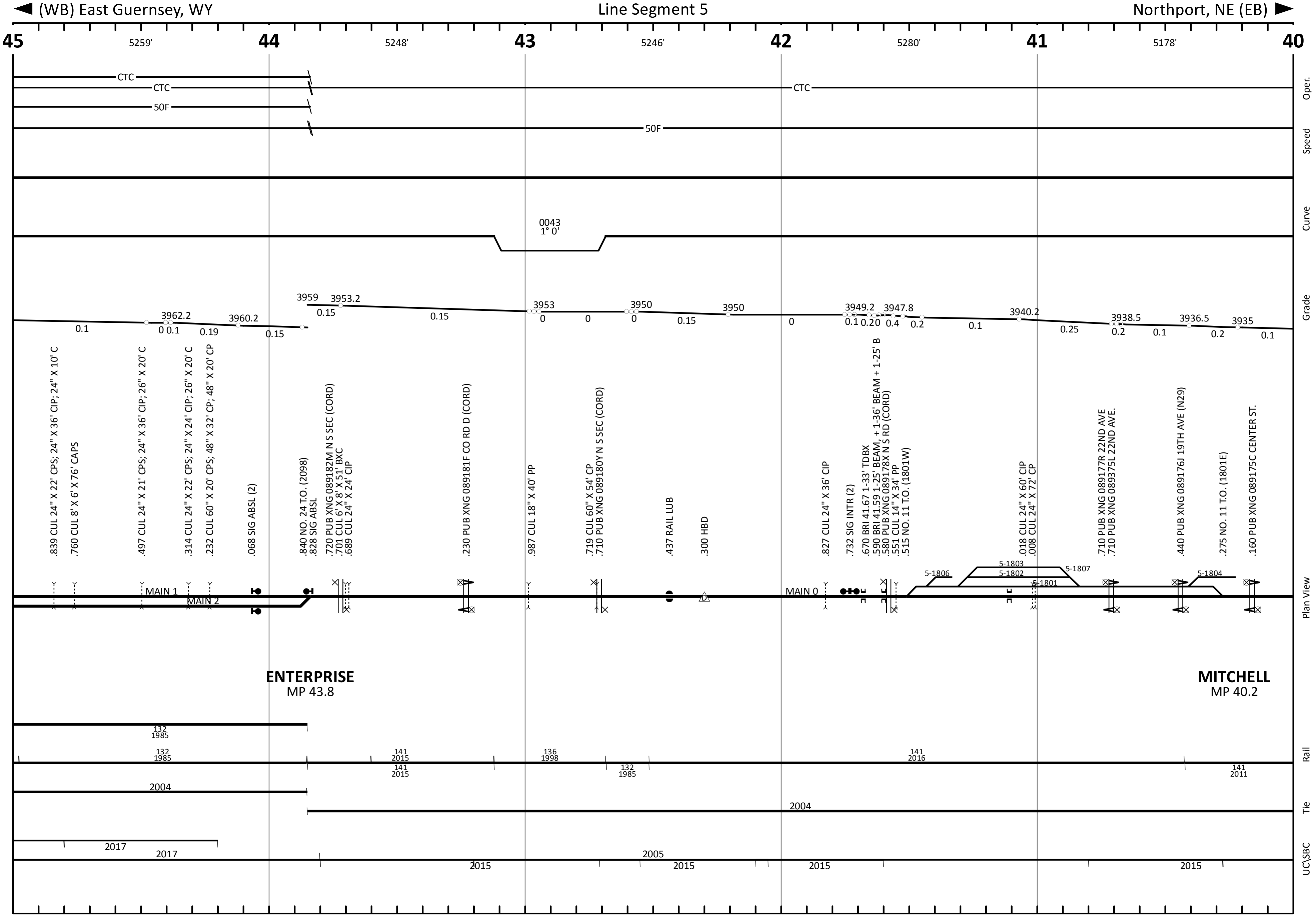
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018


50
5252'
49
5265'
48
5269'
47
5259'
46
5278'
45
CTC
CTC
50F
50F
Oper.
Speed
0050
1° 0'
0050
1° 0'
0047
0° 30'
0047A
0° 30'
Curve
4004
4004
4001
3998.1
3992.1
3992.1
3990.4
3989.8
3986.5
3979.3
3976.7
3976.7
3974.2
3973.4
3970.4
3969
3968
0.5
0.03
0
0.15
0.1
0.2
0.35
0
0.14
0.15
0
0.37
0.3
0.2
0.1
0
0.25
0.16
0
0
0.3
0.2
0.05
Grade
.431 BRI 49.43 STEEL (2)
.330 CUL 18" X 60' CP
.330 PUB XNG 089192T CO RD 5 (CORD)
.310 CUL 36" X 24' CPS; 36" X 16' CP
.301 CUL 36" X 24' CPS; 36" X 40' CP
.891 CUL 24" X 24' CPS; 24" X 36' CIP
.661 CUL 24" X 24' CIP
.558 SIG INTR (4)
.416 CUL 48" X 26' CPS; 48" X 32' CP
.395 CUL 48" X 26' CPS; 48" X 32' CP
.289 CUL 32" X 24' PS; 30" X 24' CIP
.770 PUB XNG 089189K N-SSEC (CO RD)
.760 BRI 47.76 16' PCT; + 30' TDBX; + 16' PCT (2
.594 CUL 24" X 24' CPS; 24" X 24' CIP; 24" X 3' CP
.490 CUL 24" X 24' CPS; 24" X 24' CIP; 24" X 10' C
.362 CUL 24" X 24' CPS; 24" X 36' CIP
.262 CUL 18" X 36' PP
.183 NO. 11 T.O. (2001)
.756 PUB XNG 089187W S MORRILL RD (NSL79D)
.480 NO. 11 T.O. (2004)
.380 NO. 11 T.O. (2005)
.180 PUB XNG 089186P WALSH RD
.088 SIG INTR (4)
.992 CUL 18" X 38' PS; 20" X 24' CIP
.750 PUB XNG 089185H CO RD 9 (CORD)
.733 CUL 42" X 60' CPS; 36" X 5' CPS
.732 CUL 42" X 60' CPS
.098 CUL 24" X 22' CPP; 20" X 24' CIP; 22" X 20' C
5-2003
5-2002
5-2004
5-2001
MAIN 1
MAIN 2
5-2005
5-2006
Plan View
MORRILL
MP 46.5
132
1984
136
1995
132
1985
132
1985
132
1985
141
2007
141
2007
141
2012
Rail
2004
2007
Tie
2017
2005
2010
2017
UC\SBC



![BNSF Railway]

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division
Powder River North Engineering Division

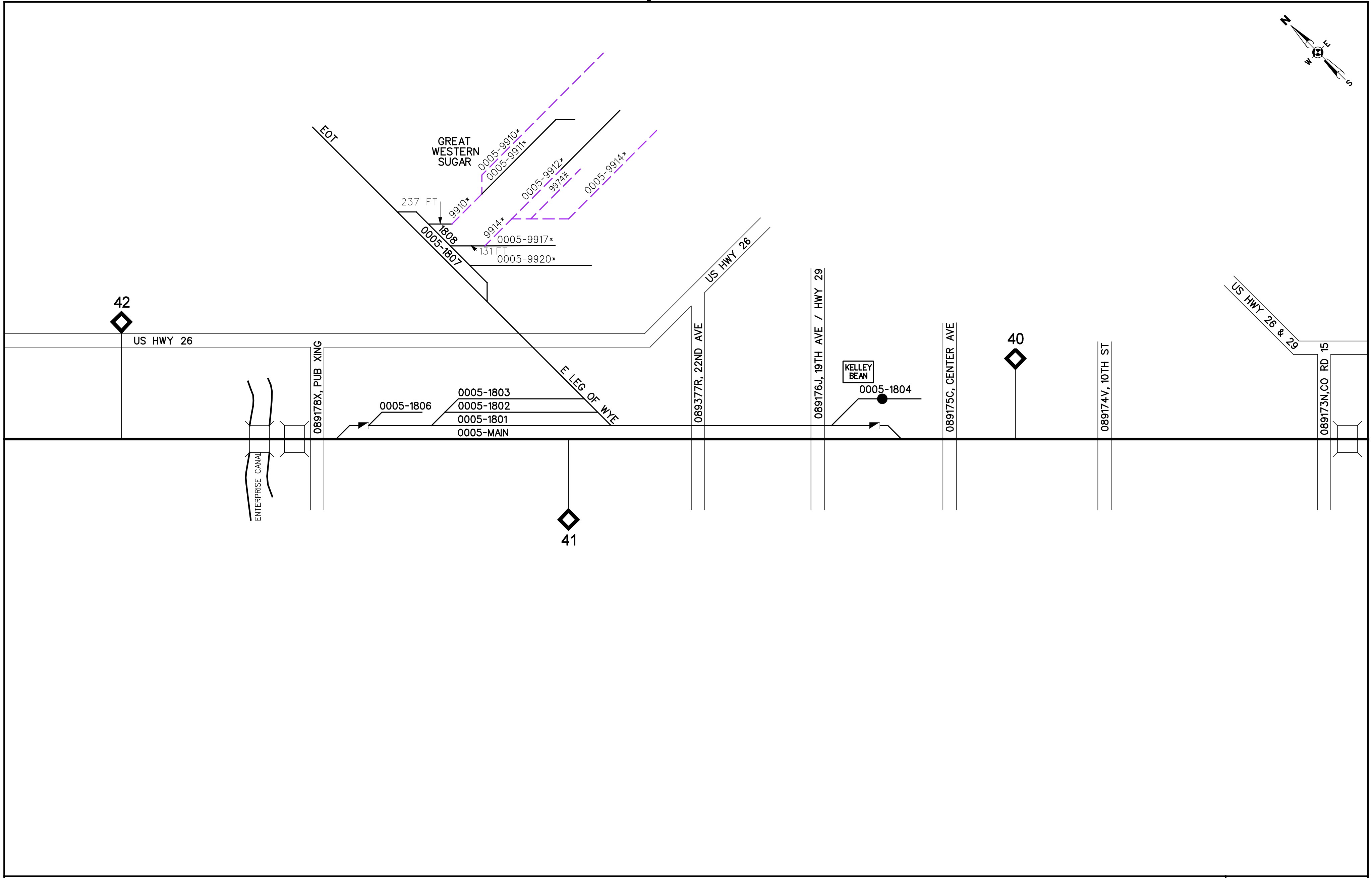
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018 Page 21 of 34

MITCHELL, NE
Valley Subdivision

← East Guernsey., WY

Northport, NE →



BNSF RAILWAY

TRACK NUMBERS:
4 DIGIT NUMBER IS A CLIC (1234)
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* UNKNOWN TRACK NUMBER

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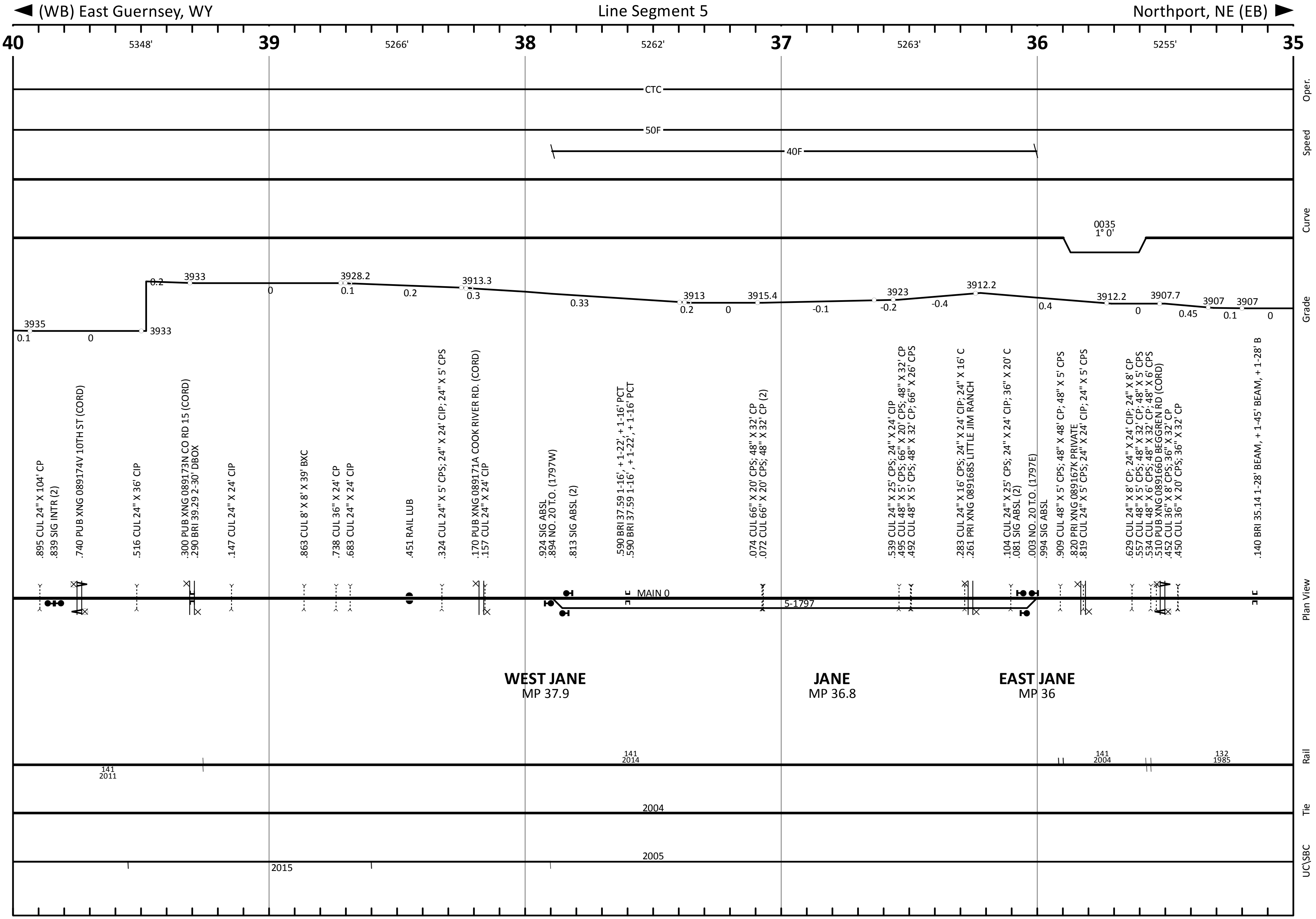
BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: MITCNE
FSAC: 32074
REVISED: 10/19/2016
TEAM: MITC18029.DGN
TRK CHT: VAL022.DGN



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division

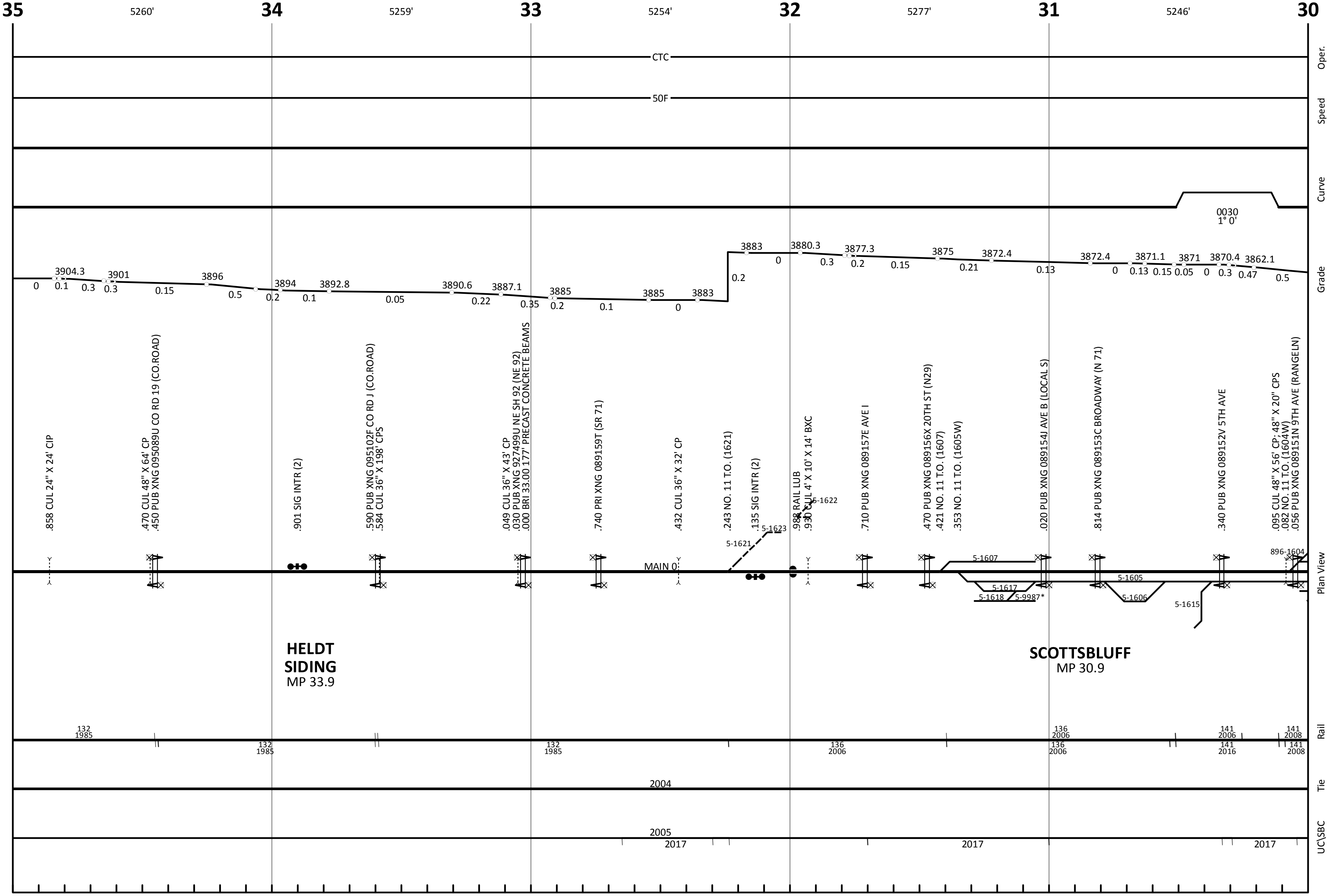
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018 Page 23 of 34

◄ (WB) East Guernsey, WY   Line Segment 5   Northport, NE (EB) ►



Valley Subdivision

Powder River Operating Division
Powder River North Engineering Division

BNSF RAILWAY
System Maintenance and Planning

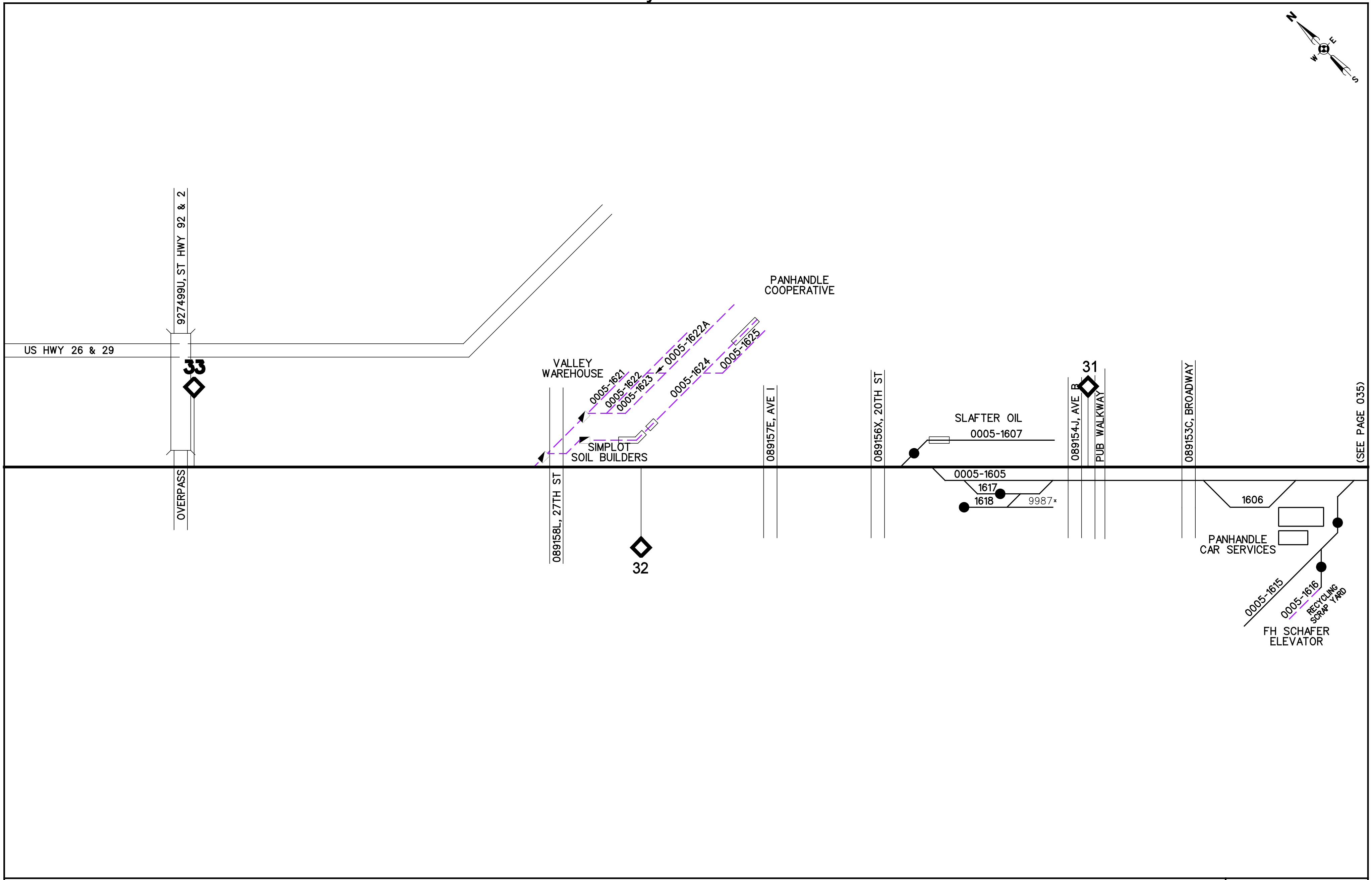
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018

SCOTTSBLUFF, NE
Valley Subdivision

◄— East Guernsey., WY

Northport, NE —►



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BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
INDUSTRY MAINT & BNSF OWNED (LEASE)
● NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪ DERAIL

JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

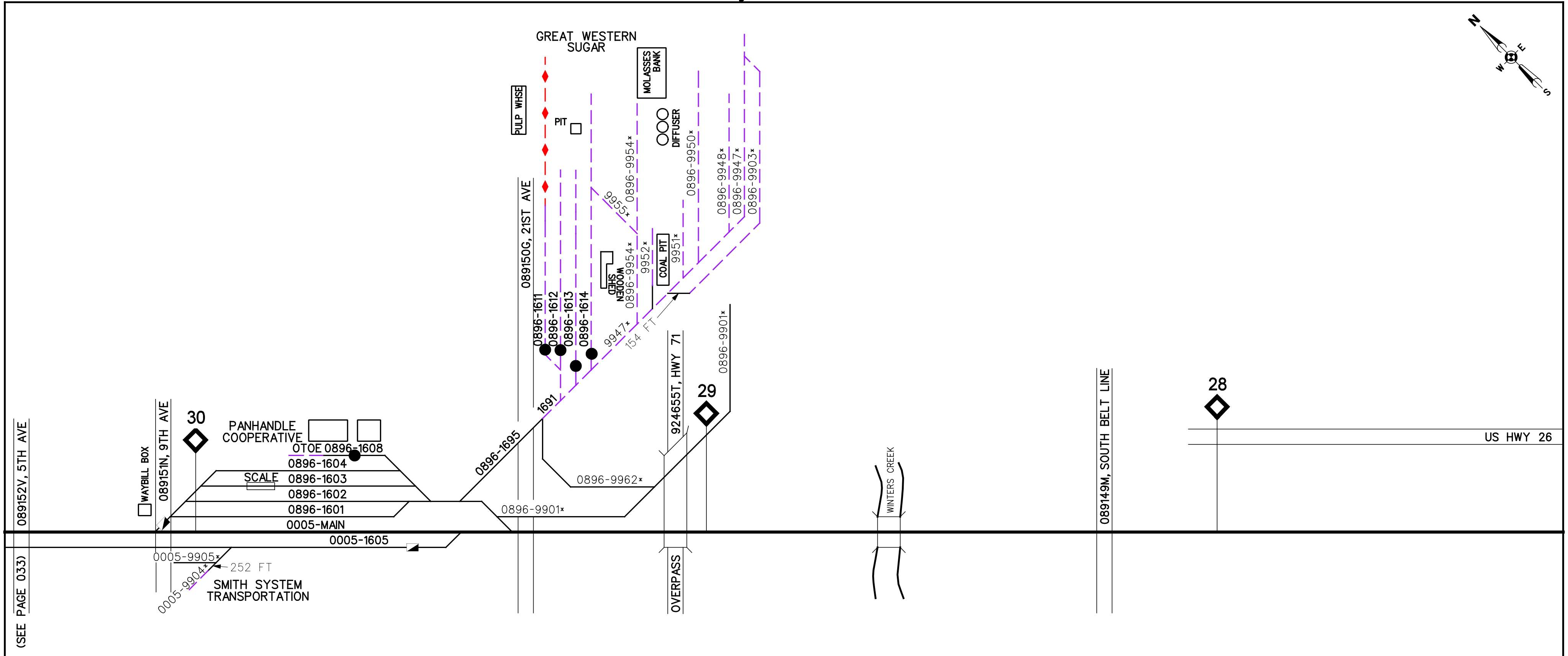
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: SCOTTS
FSAC: 32065
REVISED: 12/30/2016
TEAM: SCOT16033.DGN
TRK CHT: VAL025.DGN
TEAM PG 033

SCOTTSBLUFF, NE
Valley Subdivision

← East Guernsey., WY

Northport, NE →



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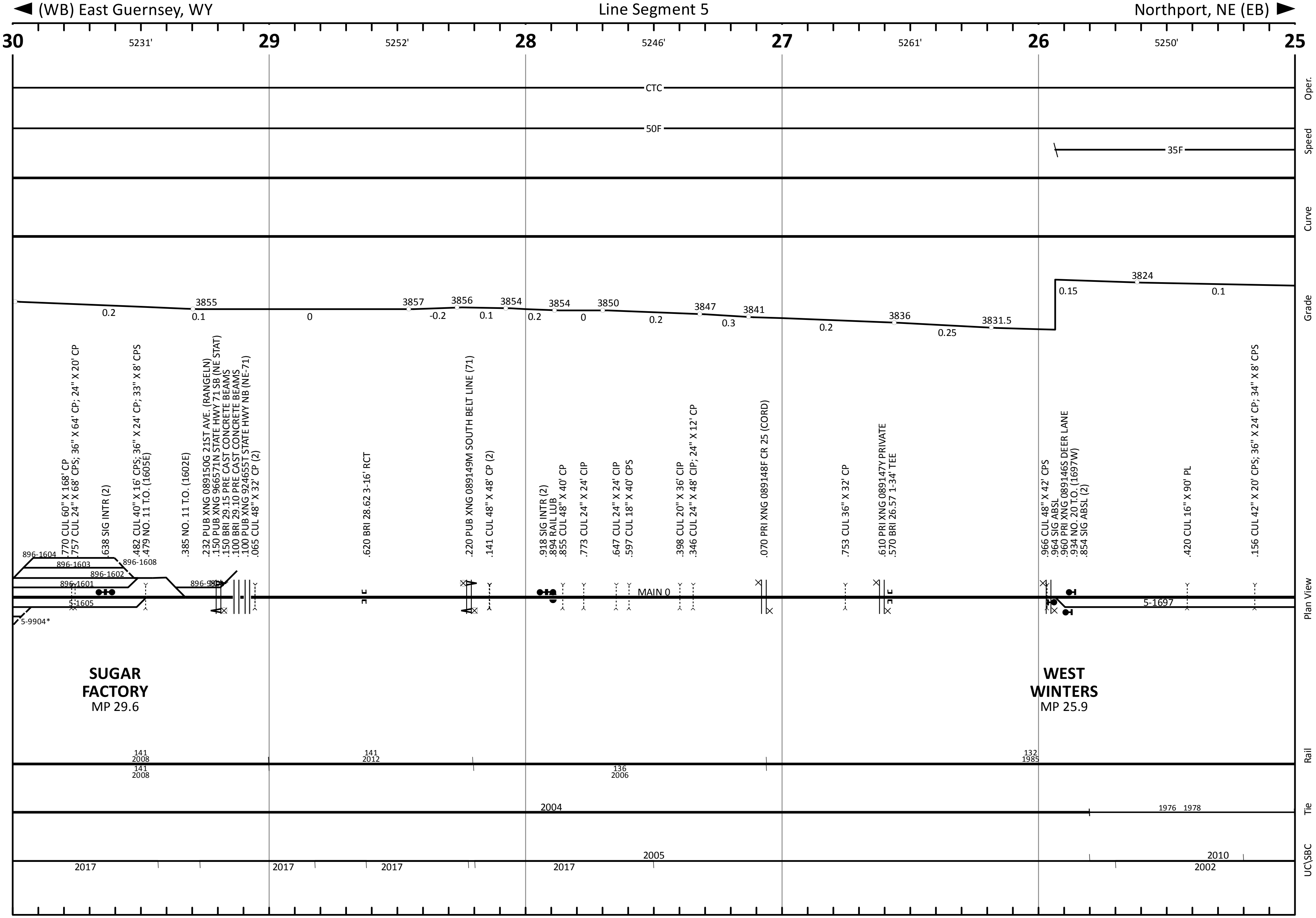
———	BNSF OWNED & MAINT
—◆—◆—	INDUSTRY OWNED & BNSF MAINT
— — —	IND OWNED & MAINT
●—●—●	INDUSTRY MAINT & BNSF OWNED (LEASE)
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT
◪	DERAIL
—┼—┼—	JOINT FACILITIES
———	TRACKAGE RIGHTS
┼┼—┼┼	FOREIGN TRACK

IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: SCOTTS
FSAC: 32065
REVISED: 12/30/2016
TEAM: SCOT16035.DGN
TRK CHT: VAL026.DGN



BNSF RAILWAY

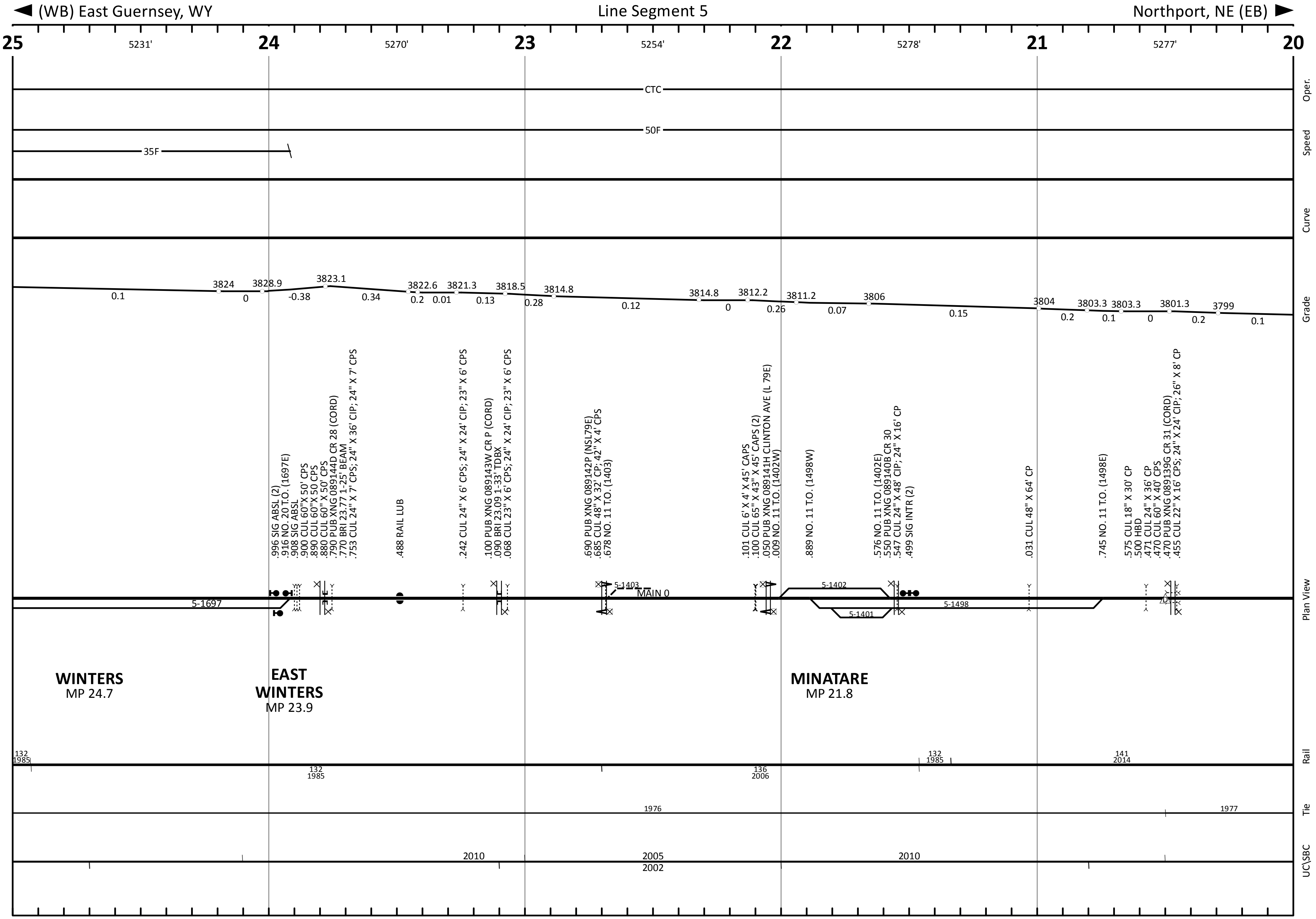
System Maintenance and Planning

Valley Subdivision

Powder River Operating Division
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com
Revised to July 19, 2018



BNSF RAILWAY

System Maintenance and Planning

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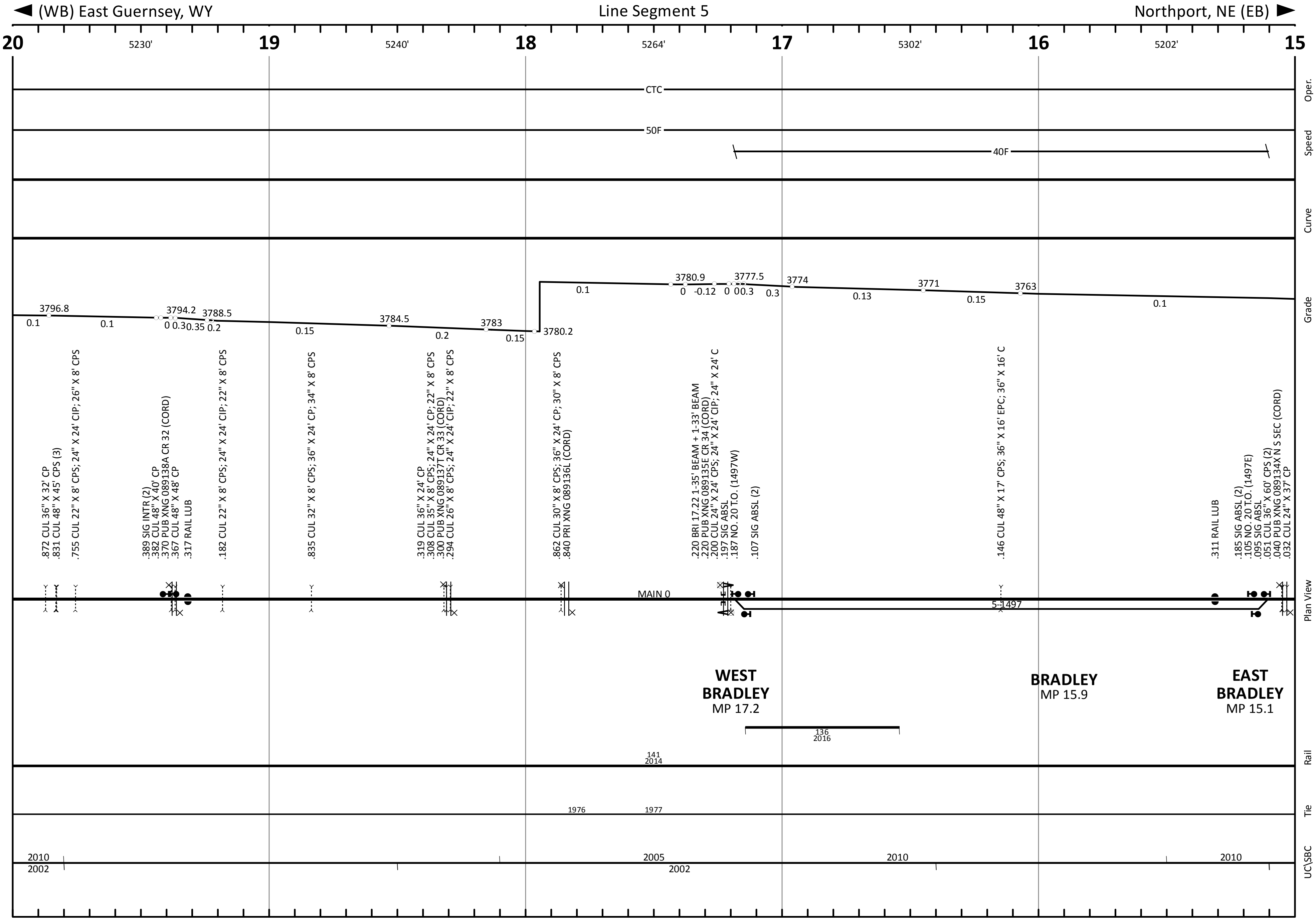
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

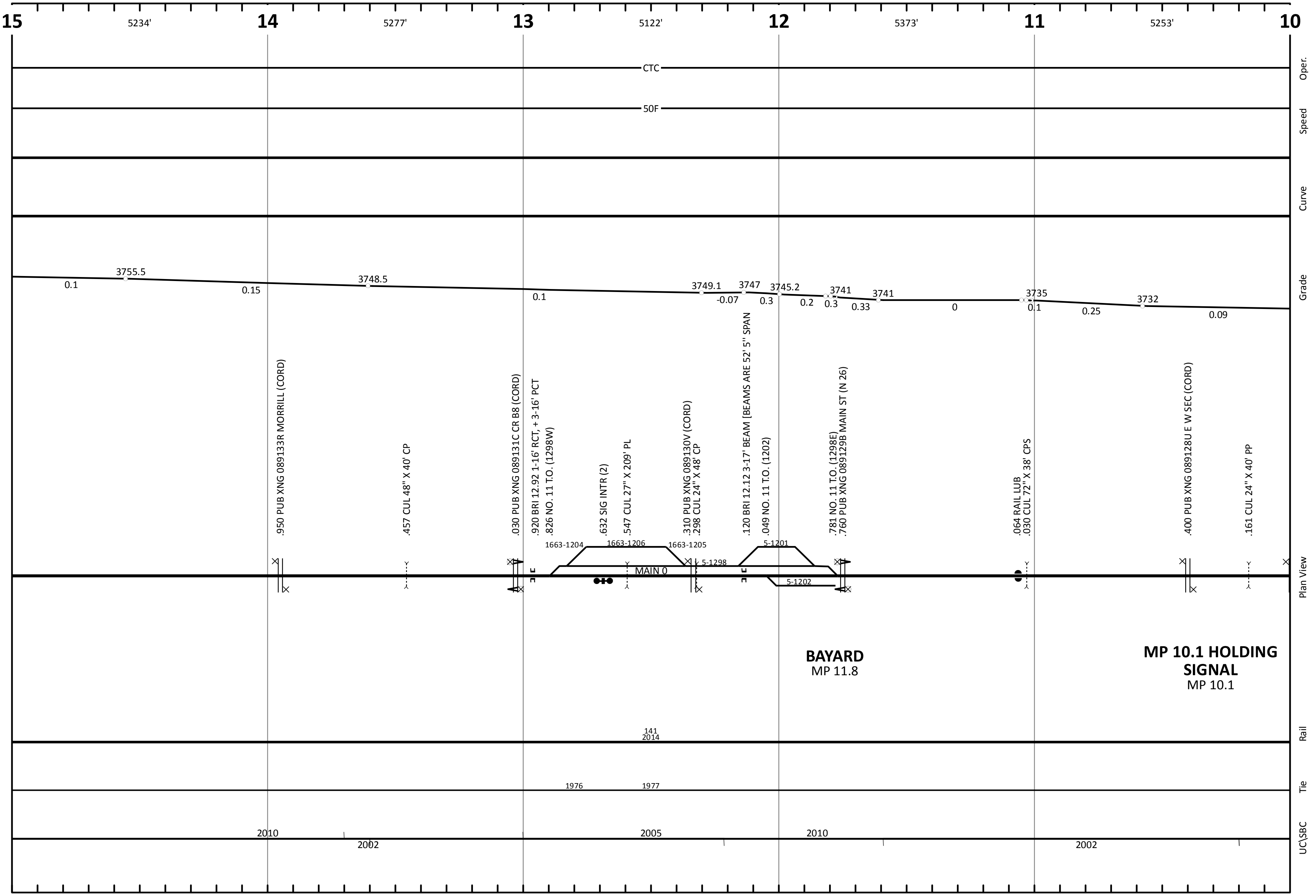
Powder River Operating Division
Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018 Page 29 of 34

◄ (WB) East Guernsey, WY Line Segment 5 Northport, NE (EB) ►



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division

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Engineering Track Chart

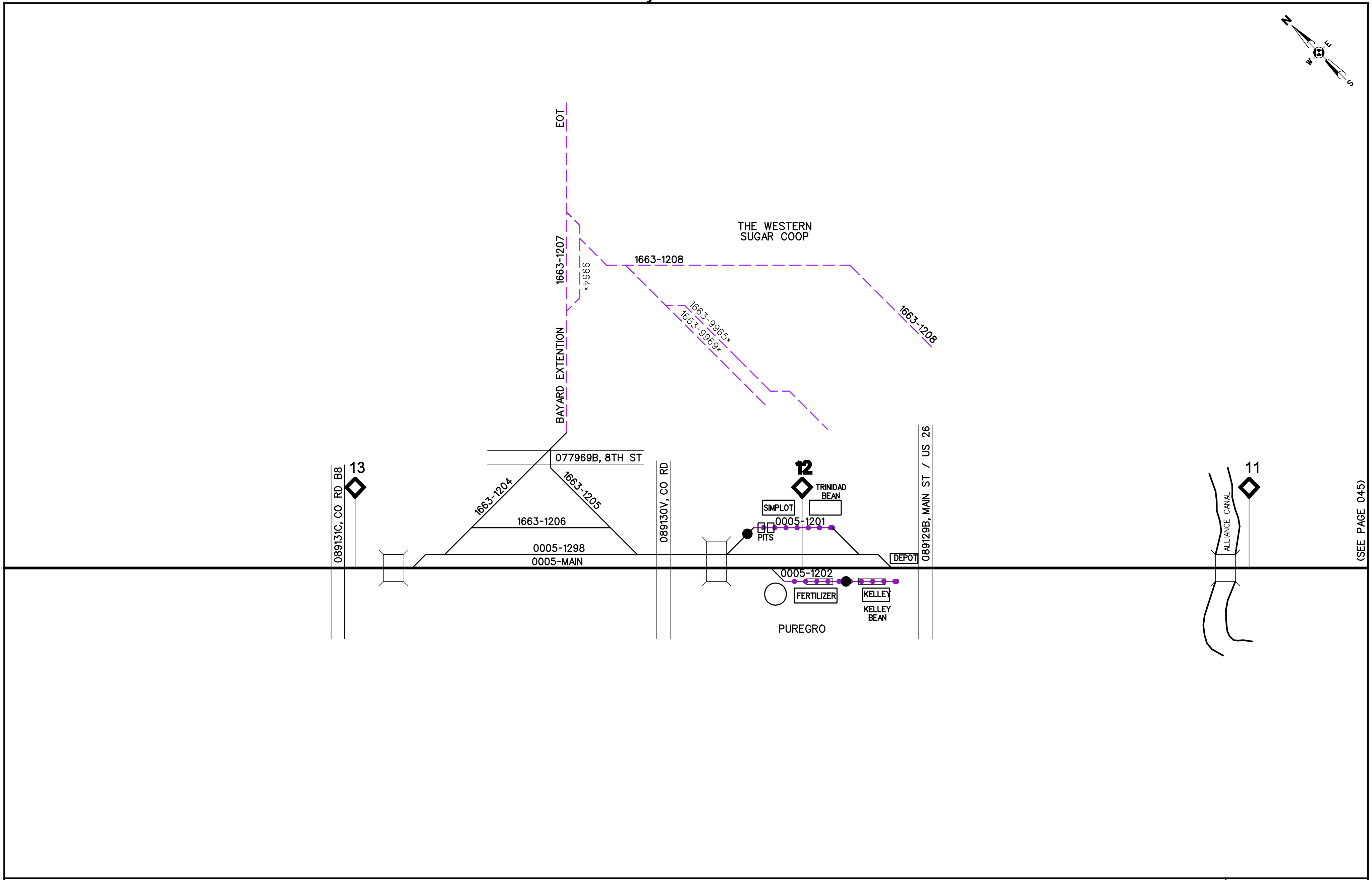
Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018

BAYARD, NE
Valley Subdivision

← East Guernsey., WY

Northport, NE →



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BNSF OWNED & MAINT
INDUSTRY OWNED & BNSF MAINT
IND OWNED & MAINT
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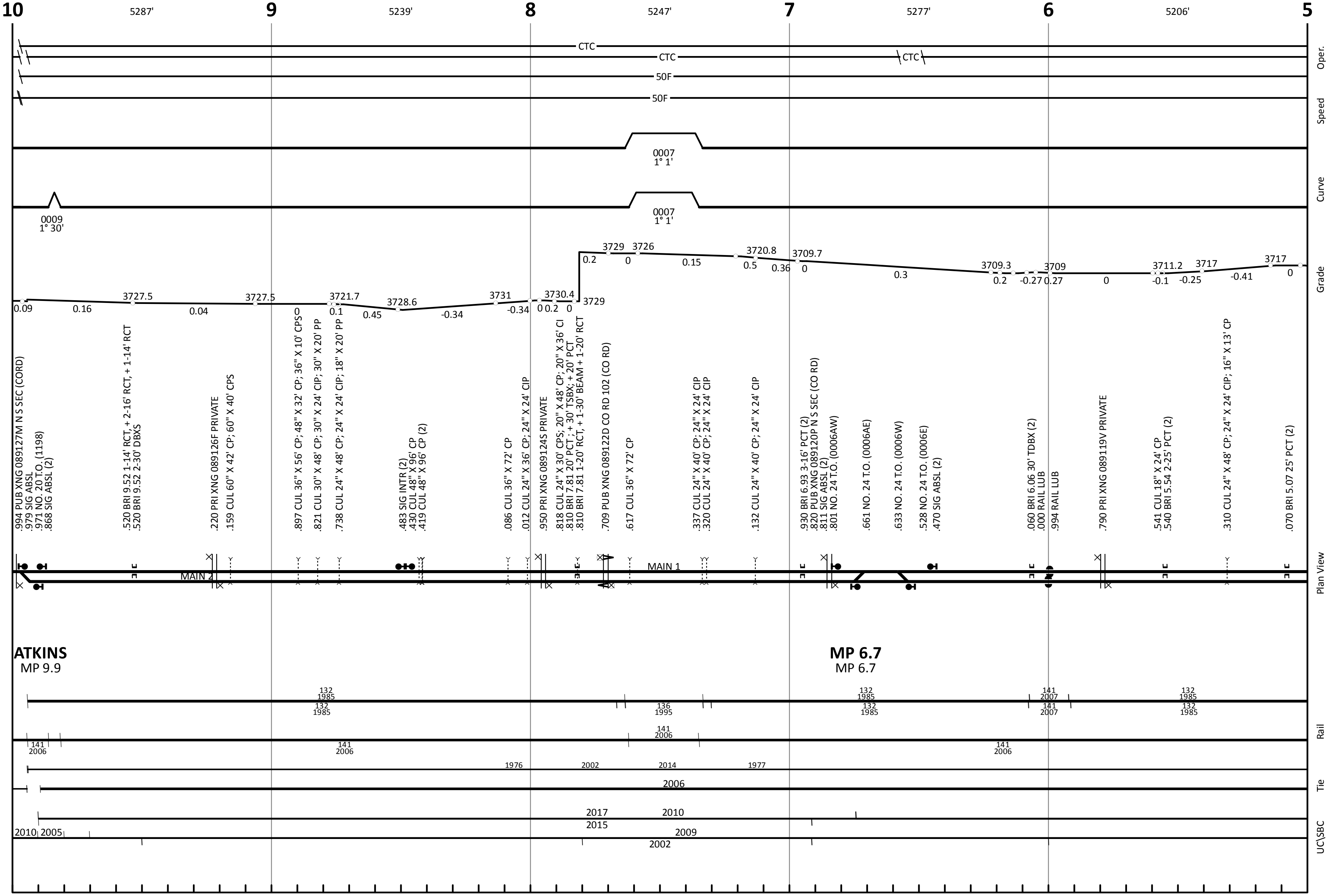
JOINT FACILITIES
TRACKAGE RIGHTS
FOREIGN TRACK

STATION ABBR: BAYANE
FSAC: 32046
REVISED: 11/16/2016
TEAM: BAYA12043.DGN
TRK CHT: VAL031.DGN

◄ (WB) East Guernsey, WY   Line Segment 5   Northport, NE (EB) ►



System Maintenance and Planning

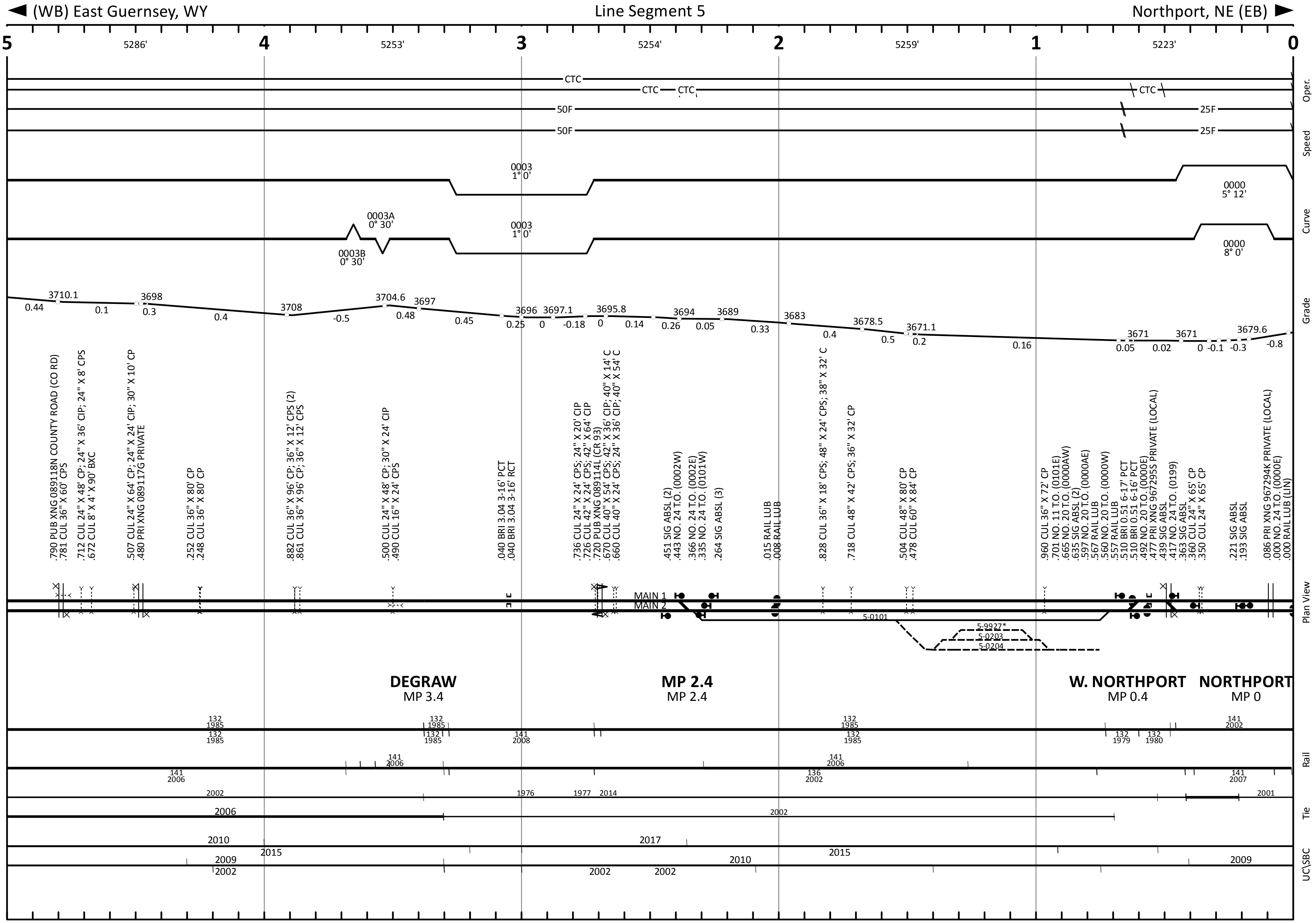
Valley Subdivision

Powder River Operating Division

Powder River North Engineering Division

Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com



BNSF RAILWAY

System Maintenance and Planning

Valley Subdivision

Powder River Operating Division

Powder River North Engineering Division

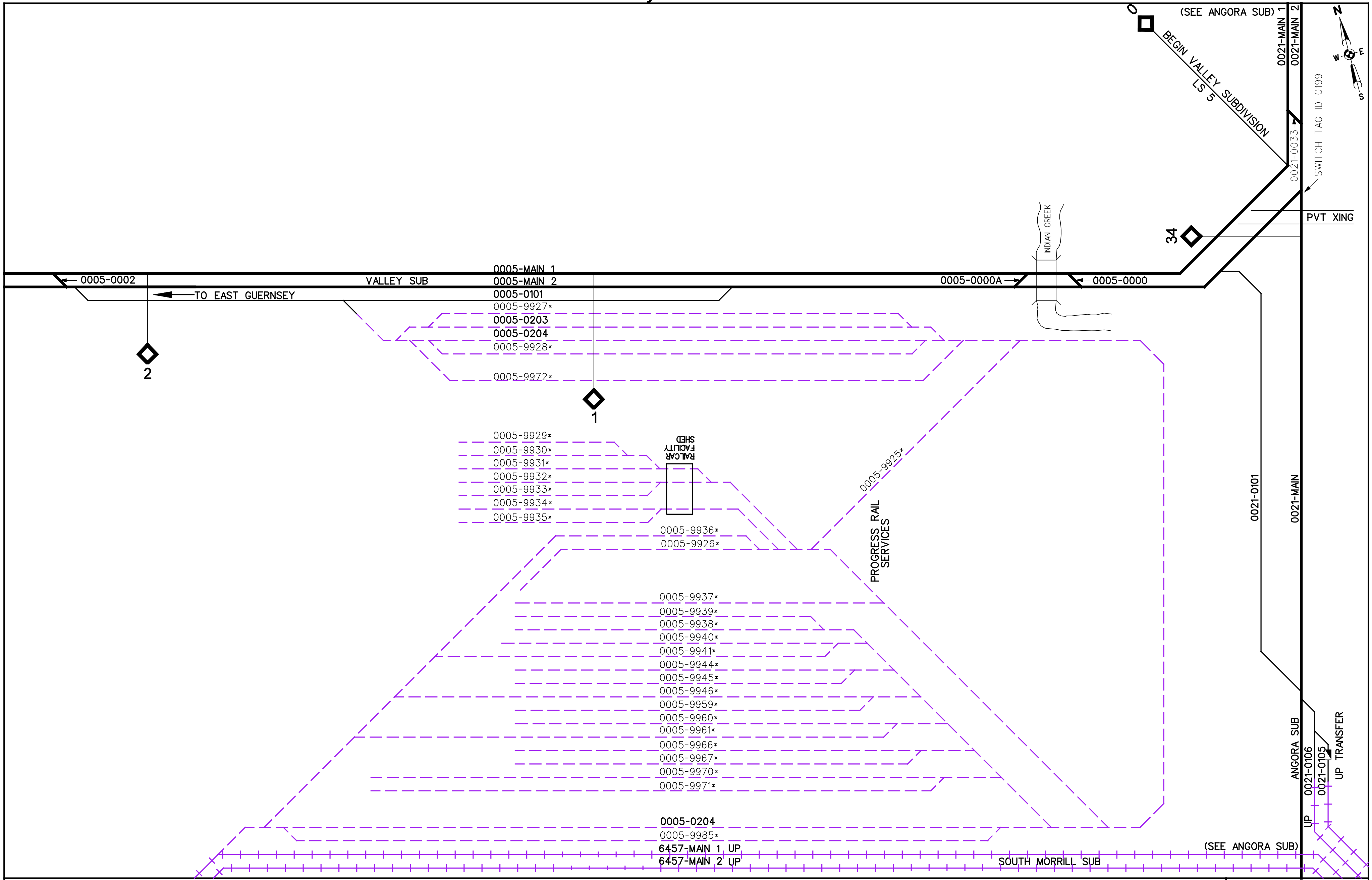
Engineering Track Chart

Updates: ENGRMASTERDATAMGMT@bnsf.com

Revised to July 19, 2018

NORTHPORT, NE
Valley Subdivision

← East Guernsey., WY



BNSF RAILWAY

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─◆─	INDUSTRY OWNED & BNSF MAINT	▬	TRACKAGE RIGHTS
- - -	IND OWNED & MAINT	┼┼┼	FOREIGN TRACK
●●●●	INDUSTRY MAINT & BNSF OWNED (LEASE)		
●	NO CLEARANCE - RESTRICTIONS APPLY FOR RIDING EQUIPMENT		
◪	DERAIL		

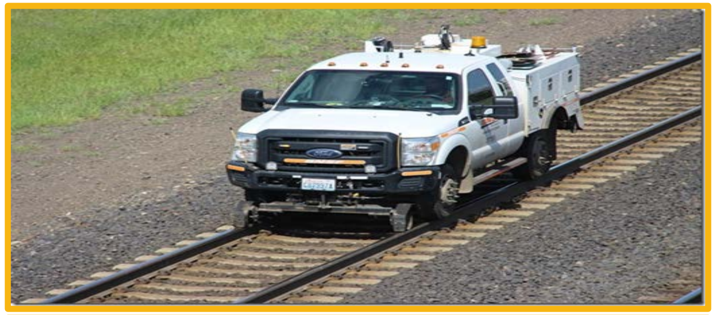
IF PURPLE OTHERS MAINTAIN (NOT BNSF)
IF RED MAINTENANCE BILLABLE TO INDUSTRY

STATION ABBR: NORTNE
FSAC: 32034
REVISED: 1/16/2014
TEAM: NORT01039.DGN
TRK CHT: VAL019A.DGN

EXHIBIT B

Phase	Days	Inspection	Metric
1	1-60	• Maintain current manual visual inspection frequency • Target of approximately weekly geometry car frequency • Joint BNSF/FRA "baseline" manual field inspection	Below 2014 baseline for: 1. Unprotected Red tags/100 miles = 6.95
2	61-120	• Weekly mandated manual visual main line inspections; monthly sidings • Target of approximately weekly mainline geometry car frequency; monthly sidings • Current turnout inspection and rail joint inspection requirements unchanged • ATIP Inspection near end of phase 2	Reduction from baseline: 1. Unprotected Red tags/100 miles = 5.0 or below measured quarterly (28% reduction)
3	121-300	• Data driven focused manual visual inspections • Twice monthly mandated manual visual mainline inspections; monthly sidings • Data driven geometry car frequency • Automated Optical inspection platform added at same frequency of track geometry testing • Current turnout inspection and rail joint inspection requirements unchanged • ATIP Test end of phase 3	Reduction from baseline: 1. Unprotected Red tags/100 miles = 5.0 or below measured quarterly (28% reduction)
4	301-365	• Data driven focused manual visual inspections • Twice monthly manual visual mainline inspections; monthly sidings • Data driven geometry car testing frequency • Data driven optical testing frequency • Current turnout inspection and rail joint inspection requirements unchanged • Additional technology tested • Joint BNSF/FRA Manual Field Inspection	Reduction from baseline: 1. Unprotected Red tags/100 miles = 5.0 or below measured quarterly (28% reduction)
5	365 - Onward	• BNSF System-wide implementation	Reduction from baseline: 1. Unprotected Red tags/100 miles

BNSF/FRA Inspection Pilot Technology



System	Technology	Description/Use
BNSF Geometry Cars ***Phases 1 – 4***	Laser, optical, and inertial vista beam	Targeted weekly testing in phase 1 and 2 and move to performance based frequency in phases 3 and 4 for surface and gage defects. Data will be analyzed to understand where maintenance and inspection activities need to be focused.
Hyrail Geometry Vehicles ***Phases 1 – 4***	Laser, optical, and mechanical measurement	Spot testing for surface and gage defects in any gaps left by the rail bound geometry cars to ensure compliance with pilot requirements.
Optical system ***Phases 3 & 4***	NxGen and/or internal (THOR)	Camera mounted platform to identify visual defects targeting the same inspection frequency as the geometry cars and added in phases three and four.

BNSF Inspection Technologies**

System	Technology	Description/Use
Ground Penetrating Radar (GPR)	Balfour-Beatty, Zetica Rail	2GHz and 400MHz antennas to determine ballast Fouling, free-draining layer depth down to 18”; on-demand track bed analysis down to 4’. Typically tested every 1-3 years.
Aurora Tie Inspection	Georgetown Rail	Inspection vehicle uses X-Ray technology to grade the quality of our cross ties to help inform our maintenance plans. Typically tested every 1-3 years.
Vehicle Track Interaction (VTI)	Ensco	62 locomotive mounted units (system wide) that operate using accelerometers to find and communicate exceptions to BNSF. A locomotive with a VTI unit traverses the pilot territory approximately 10 times per month.

***this technology is not part of the pilot, but will continue to be deployed periodically across the pilot territory as part of BNSF’s normal maintenance .*

BNSF Inspection Technologies** (cont.)

System	Technology	Description/Use
Rail Detector	Sperry, Herzog	Ultrasonically detected internal rail flaw types, sizes, lengths, and locations. Typically test 19 to 65 days contingent upon tonnage and service failure rates on the pilot territory.

***this technology is not part of the pilot, but will continue to be deployed periodically across the pilot territory as part of BNSF's normal maintenance .*

<u>Exhibit 11</u>

JOHN CECH
VP Engineering – Track & Structures

BNSF Railway Company
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Phone: (817) 352-2164
Email: John.Cech@bnsf.com

August 31, 2018

Robert E. Lauby
Associate Administrator Railroad Safety
Federal Railroad Administration
1200 New Jersey Ave, S.E.
Washington, D.C. 20590

Re:Supplement to BNSF's Petition for Temporary Suspension of 49 C.F.R § 213.233(c)

Dear Mr. Lauby:

After consultation and discussion with FRA staff, BNSF hereby supplements and amends its petition for temporary suspension of 49 C.F.R. § 213.233(b) and (c) to allow for the testing of automated track inspection methods utilizing new technologies in the following ways:

- oBNSF seeks relief during the pilot only from the requirements of 49 C.F.R. §213.233(c)
- oThe pilot will consist of 4 phases. Phase 5, as originally outlined on Exhibit B to the pilot document, will not be a part of the pilot;
- oDuring phases 3 and 4 of the pilot, BNSF will conduct at least two geometry car and optical tests per month;
- oCondition 4 of the proposed pilot has been revised to reflect a 24 hour review period (rather than the original 48 hour proposal). Additionally, two class drops will be verified and protected immediately upon data validation. Performance metrics in condition 4 changes to 4.8/100 miles in phase 3 and 4.6/100 miles in phase 4.

FRA also requested additional information as to BNSF's reasoning for choosing the proposed route for the pilot. The chosen route serves as good representation of the broader system so that a successful pilot would be indicative of potential success elsewhere on the BNSF network. Much of the territory consists of premium fastener concrete ties with twenty plus years of life remaining. Wood tie replacement is targeted at around the 815 defective ties/mile level so that we have approximately 75% non-defective ties in those wood tie segments. The standard for rail replacement on the chosen route is 141# premium rail for both curves and tangents, and we have the highest density of premium swing nose frog turnouts on our network on the coal loop. Additionally, BNSF invests significant capital maintaining the infrastructure on this route each year. We have invested close to $780M rail, tie, ballast, and other track material projects on the Powder River Division over the past 5 years.

Please do not hesitate to reach out if there is something in the petition that you would like to discuss further.

Sincerely,

John Cech

John Cech
Vice President, Engineering

CC: Thomas Herrmann – FRA
Steve Anderson – BNSF
Dave Freeman - BNSF

Exhibit 12

U.S. Department
of Transportation

**Federal Railroad
Administration**

Administrator

1200 New Jersey Avenue, SE
Washington, DC 20590

Mr. John Cech
Vice President, Engineering
BNSF Railway Company
2600 Lou Menk Drive
Fort Worth, TX 76131

SEP 2 6 2018

RE: Petition for a Temporary Suspension of 49 C.F.R. § 213.233(c)

Dear Mr. Cech:

This letter is in response to BNSF Railway's (BNSF) July 31, 2018, petition to the Federal Railroad Administration (FRA) seeking a temporary suspension of 49 C.F.R. § 213.233(c). BNSF requests a temporary suspension of these regulatory requirements under 49 C.F.R. § 211.51 *Tests* (Section 211.51), to conduct a pilot program testing various types of automated track inspection methodologies on portions of BNSF's Powder River Division main line and siding tracks.

The BNSF submission included a cover letter and the following documents:

a) Petition for a temporary suspension of 49 C.F.R. § 213.233(b) and (c) to allow for the testing of automated track inspection methodologies;
b) Exhibit A-1 (providing a description of the pilot territory, including the specific track segments included in the pilot program);
c) Exhibit A-2 (providing track charts of the track segments contained in Exhibit A-1);
d) Exhibit B (table outlining the phases of the pilot program);
e) Exhibit B-2 (titled "BNSF/FRA Inspection Pilot Technology"); and
f) Letter dated August 31, 2018, from John Cech, VP Engineering-Track & Structures, BNSF Railway to Robert Lauby, FRA (supplementing BNSF's Petition for temporary suspension).[1]

FRA considers the above-mentioned documents to constitute a test program under Section 211.51 (the Test Program). FRA has reviewed and approved the Test Program and has

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[1] BNSF's August 31, 2018, letter revises its July 31, 2018, petition and the Exhibits to that petition in several respects. First, it clarifies that BNSF is seeking relief only from the requirements of paragraph (c) of § 213.233 and only for phases 1-4 identified in Exhibit B. Second, the letter clarifies that during phases 3 and 4 of the pilot program, BNSF will conduct at least two geometry car and optical tests per month. Third, the letter revises parameter number 4 included in BNSF's petition to reflect a 24-hour period field verification deadline (as opposed to a 48-hour deadline) and to specify that two class drops will be verified and protected immediately upon data validation. Finally, the letter also revises parameter number 4 of BNSF's petition to reflect revised performance metrics (i.e., 4.8 unprotected red tags (URT)/100 miles in phase 3 and 4.6 URT/100 miles in phase 4).

determined that it is necessary for FRA to temporarily suspend the requirements of paragraph (c) of 49 C.F.R. § 213.233 to enable BNSF to conduct the Test Program.

Section 211.51(a)(2) requires that temporary suspensions be "limited in scope" as necessary to facilitate the conduct of the Test Program. Exhibit A-1 of the Test Program specifies the track segments involved in the pilot program. The Petition states that BNSF will conduct the pilot program on the identified track segments spanning seven subdivisions of its Powder River Division, covering approximately 1,348 miles of track. The Petition indicates that the pilot program is designed to specifically test the unmanned automated track geometry car (UTGC) for track inspection as a viable alternative to manual visual inspection and to implement and test an optical visual platform to supplement manual visual inspections. Given these parameters, FRA believes the Test Program is limited in scope as required by Section 211.51.

The Petition also indicates that several other track inspection technologies including ground penetrating radar (GPR), Vehicle Track Interaction (VTI), Aurora cars, and ultrasonic rail inspection will be utilized during the Test Program to supplement manual visual inspections. BNSF's petition, however, specifically excludes these technologies from the pilot program but notes that BNSF will continue to deploy the technologies across the pilot territory as part of BNSF's normal maintenance program. Accordingly, FRA does not consider these systems as within the scope of the requested suspension (i.e., utilization of these systems will not relieve BNSF from the need to comply with 49 C.F.R. § 213.233(c)). FRA does, however, encourage BNSF to use these systems during the Test Program and recommends that BNSF maintain appropriate data that may prove useful in determining the abilities of such technology to identify conditions not in compliance with the requirements of FRA's track safety standards or other potential conditions of concern.

Exhibit B of BNSF's submission describes a gradual decrease of the twice-a-week manual visual inspection frequency currently required by § 213.233(c) and BNSF's plan to augment the reduced manual visual inspections with inspections conducted by the UTGC and the optical visual inspection platform. FRA has previously granted other railroads permission to utilize track geometry cars to supplement manual visual inspections. FRA believes that the Test Program contains provisions to require the observance of standards and inspection protocols sufficient to assure the safety of train operations over the identified tracks as required in 49 C.F.R. § 211.51(a)(3). Exhibit B of the Test Program also makes clear that BNSF's existing turnout and rail joint inspection requirements will remain unchanged during the Test Program. Thus, all turnouts and rail joints that are within the geographic bounds of the pilot program will continue to be inspected per the requirements contained in 49 C.F.R. § 213.233.

Based on the above, FRA approves BNSF's Test Program and grants BNSF's petition for a temporary suspension of 49 C.F.R. § 213.233(c) limited in scope and application to that described in BNSF's Test Program, subject to the following conditions:

1. The suspension applies only to the track segments specified the Exhibit A-1 of the Test Program (Test Territory). The suspension does not apply to turnouts and rail joints in the test territory.

2. FRA may use one of its Automated Track Inspection Program (ATIP) cars equipped with an autonomous track inspection system to accompany BNSF's UTGC in the same train consist during the first phase of the pilot program. FRA ATIP cars may conduct additional audits during any phase.

3. Prior to the start of Phase 3 of the Test Program, BNSF must submit to FRA a document detailing how it will implement the "data driven focused manual visual inspections" in Phases 3 and 4 of the Test Program. This document must detail the methodology BNSF will use to implement these manual visual inspections to ensure that relevant track components in 49 C.F.R. Part 213, Subparts B and D are adequately inspected.

4. BNSF must use the metrics specified in the Test Program to monitor and measure the effectiveness of the UTGC and the optical visual platform inspections. BNSF must revise the Test Program if the metrics cannot be achieved in any phase.

5. BNSF must provide FRA with the calibration procedures and calibration frequency for the UTGC prior to the start of Phase 1 of the Test Program and for the optical visual platform prior to the start of Phase 3 of the Test Program.

6. The twice-monthly main line visual inspections must be conducted with at least ten (10) calendar days between inspections in Phases 3 and 4.

7. Track segments not inspected by the UTGC and the optical visual platform per the schedule contained in Exhibit B of BNSF's submission must be inspected in accordance with the requirements of 49 C.F.R. § 213.233.

8. Additional new technology may be tested in conjunction with the UTGC and optical visual platform inspections, but such inspections will not be used as a substitute for manual visual inspections, UTGC, or optical visual platform inspections.

9. BNSF must report to FRA all track caused derailments that occur on track segments that are part of the Test Program, regardless of monetary damage.

10. BNSF must submit monthly data on inspections and the related inspection reports to FRA during the Test Program. The reports must be in tabular format and include all manual visual inspections and all UTGC and optical visual platform inspections. The reports must indicate the method of inspection utilized and include all defects found during each inspection. At a minimum, the defect entries must include, inspection time, location (Subdivision, milepost, GPS coordinates), defect type and value, time of verification and initial remedial action, and time of permanent repair.

11. BNSF will provide records kept in current practice detailing BNSF's track maintenance and/or repair work related to the pilot program within 30 days of receiving such a request from FRA.

The Test Program and related temporary suspension of 49 C.F.R. § 213.233(c) is initially valid for one (1) year from the date of this letter. FRA reserves the right to modify or rescind this temporary suspension upon receipt of information pertaining to the safety of rail operations or in the event of non-compliance with any condition related to this approval. In addition, based on consideration and analysis of valid performance data gathered during the Test Program, upon BNSF's written request, FRA will consider modifying the duration of this approval (and either accelerating the Test Program or extending the duration of this approval) as appropriate. As such, FRA looks forward to a continual dialogue with BNSF on the findings of the Test Program as it is implemented.

Unless otherwise designated, all submissions of data and information should be made to FRA's Associate Administrator for Railroad Safety & Chief Safety Officer. If you have any questions, please contact Dr. Yu-Jiang Zhang, FRA Staff Director, Track Division at (202) 493-6460 or yujiang.zhang@dot.gov.

Sincerely,

Ronald Batory

Ronald Batory
Administrator

cc. Steve Anderson, BNSF

Exhibit 13

BNSF
RAILWAY

JOHN CECH
VP Engineering – Track & Structures

BNSF Railway Company
2600 Lou Menk Drive
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October 19, 2018

Robert E. Lauby
Associate Administrator Railroad Safety
Federal Railroad Administration
1200 New Jersey Ave, S.E.
Washington, D.C. 20590

Re:Request for Clarification concerning FRA's Grant of BNSF's Petition for Temporary Suspension of 49 C.F.R. § 213.233(c)

Dear Mr. Lauby:

After consultation and discussion with FRA staff, BNSF hereby clarifies its position on inspection of rail joints and turnouts. BNSF will continue to manually, visually inspect turnouts monthly in accordance with 49 C.F.R. §213.235 and will conduct manual, visual inspections of rail joints at the same frequency as other track in accordance with the phasing reflected on Exhibit B. Additionally, BNSF will conduct detailed walking inspections of rail joints in accordance with 6.2 of BNSF's CWR policy as mandated by §213.119. As with other aspects of the pilot, BNSF intends to use data driven analysis to determine if additional manual inspections are warranted for turnouts and joints in phases 3 and 4 of the pilot. Additionally, the optical system will inspect rail joints in phase 3 and 4 as part of the pilot. An updated version of Exhibit B is attached for you review.

BNSF further clarifies that geometry car testing mentioned in the phasing document could potentially include a manned track geometry car during any phase of the pilot. While BNSF intends to conduct a majority of the testing using an unmanned car, operational needs may require substitution of the manned geometry car in some instances.

Please do not hesitate to reach out if there is something that you would like to discuss further.

Sincerely,
John Cech

John Cech
Vice President, Engineering

Cc:Karl Alexy
Tom Herrmann
Yu-Jiang Zhang

Exhibit 14

U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

OCT 24 2018

Mr. John Cech
Vice President, Engineering
BNSF Railway Company
2600 Lou Menk Drive
Fort Worth, TX 76131

RE: Request for Clarification concerning FRA's Grant of BNSF's Petition for Temporary Suspension of 49 C.F.R. § 213.233(c)

Dear Mr. Cech:

This letter is in response to BNSF Railway Company's (BNSF) October 19, 2018, letter to the Federal Railroad Administration (FRA) clarifying portions of the test program approved by FRA's Administrator by letter dated September 26, 2018, and involving a temporary suspension of Title 49 of the Code of Federal Regulations (C.F.R.) § 213.233(c) of the Federal Track Safety Standards.

FRA understands that BNSF intends to begin phase 1 of the test program on November 1, 2018. In its letter, BNSF also clarified that it was reserving the option to use manned geometry vehicles in any phase of the test program in lieu of unmanned inspection vehicles. BNSF also provided a new Exhibit B outlining the phases of the test program. This new Exhibit B amends the previous Exhibit B that was part of BNSF's Test Program. First, the new Exhibit B makes clear that turnouts and rail joints are included within the scope of the test program and the suspension of § 213.233(c). Second, this new Exhibit B clarifies that in phases 3 and 4 of the test program, BNSF will conduct a minimum of 2 geometry car inspections per month on all track within the test territory. Finally, this new Exhibit B amends the metrics specified in the original Exhibit B to incorporate the metrics specified in FRA's September 26, 2018 approval letter. [1]

FRA does not object to any of these clarifications or modifications and considers the revised Exhibit B provided with BNSF's October 19, 2018 letter to supersede the Exhibit B referenced in FRA's September 26, 2018 approval letter. FRA also specifically acknowledges that FRA's temporary suspension of § 213.233(c) extends to rail joints and turnouts in the test territory. Accordingly, numbered paragraph one in FRA's September 26, 2018 letter approving BNSF's suspension request and related test program is revised to read as follows:

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[1] The second and third noted revisions to Exhibit B were previously made part of BNSF's test program by way of an August 31, 2018 letter to FRA from John Cech, VP Engineering-Track Structures, BNSF.

1. The suspension applies only to the track segments specified in Exhibit A-1 of the Test Program (Test Territory).

If you have any questions, please contact Dr. Yu-Jiang Zhang, FRA Staff Director, Track Division at (202) 493-6460 or yujiang.zhang@dot.gov.

Sincerely,

Thomas Herrmann
Director, Office of Technical Oversight
Office of Railroad Safety