On Track for Resilience: Rail-to-Grid Power Generation

Energy and Water Projects (EW20-5241)

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The objective of this project is to conduct a feasibility study to evaluate the use of existing Army diesel-electric locomotives as a mobile backup electric generation solution for DoD facilities. The study investigates how diesel-electric locomotives can be implemented from technical, operational, applicability, economic, and resiliency perspectives.

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Abstract

Most Department of Defense (DoD) installations are dependent on standalone diesel backup generators to supply power to mission critical facilities. In order to operate these generators during extended power outages the installation must have sufficient fuel stored in integrated fuel tanks or the capacity to deliver fuel to the backup generators throughout the duration of the outage. However, backup generators must be tested and maintained to operate effectively. With the large number of distributed generators that many installations own maintenance can fall behind causing unexpectedly high failure rates. In addition to high failure rates, creating n+1 redundancy for standalone generators is extremely expensive since it would require purchasing and maintaining two generators at each critical facility. A cost-effective, flexible, centrally fueled, and easy-to-maintain solution to provide redundant power generation would serve the unmet gap in installation energy resilience over long term power outages.

The U.S. Army owns eighty-seven diesel-electric locomotives that are ideally suited to meet emergency energy resilience demands, while still being utilized during routine mission execution. Locomotives use diesel engines to operate generators, which in turn produce electric power to drive traction motors. However, traction motors can be decoupled from the generator, allowing the power generated to be supplied to local buildings or grids. There are 25 units rated at 1.5 megawatts (MW) each, 53 rated at 1.3 MW each, and 9 units rated at 2.2 MW each. In total, the Army's locomotive fleet has a combined power output capability of 123 MW. Such a mobile generation capacity could economically enhance mission resilience. Additionally, locomotives have the capability to haul their fuel with them through utilization of railroad tank cars. Army Material Command (AMC) estimates that one 25,000-gallon tank car of diesel represents 11.5 MW-days of energy after efficiency losses. In essence, an 820 kW load could be operated for 14-days off one locomotive and one tank car, meeting the Army Directive. If additional fuel is required due to large loads or lengthier outages, more tank cars can be hauled with the locomotive or brought in as needed.

The objective of this project is to conduct a feasibility study to evaluate the use of existing Army diesel-electric locomotives as a mobile backup electric generation solution for DoD facilities. The study investigates how diesel-electric locomotives can be implemented from technical, operational, applicability, economic, and resiliency perspectives.

Unfortunately, the rail-to-grid backup power solution did not pass the performance assessment to be considered as a widespread, main backup power strategy. While the technology is technically feasible, under current real-world conditions it performs worse from operational, applicability, most economic, and resilience standpoints as compared to the traditional backup power benchmark. In addition to these, it also relies on a long list of significant assumptions that put the project at risk during the complexity of an emergency scenario. The last couple years have demonstrated the importance of investing in reliable infrastructure without the need for complex supply chains and interdependencies when it matters most. Consequently, the motto holds true: "Let us be efficient where we can, and effective where we must." And mission critical backup power is a must.

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List of Acronyms and Abbreviations

Acronym	Meaning
AAR	American Association of Railroads
AC	Alternating Current
AFB	Air Force Base
AMC	Army Materiel Command
ASC	Army Sustainment Command
BLCC	Building Life Cycle Cost
BNSF	Burlington Northern Santa Fe
CERL	Construction Engineering Research Laboratory
CSX	Chessie Seaboard Consolidated (Railroad)
DC	Direct Current
DER	Distributed Energy Resource
DoD	Department of Defense
DoE	Department of Energy
DOT	Department of Transportation
DPW	Department of Public Works
EIA	Energy Information Administration
EPRI	Electric Power Research Institute
ERDC	Engineering Research and Development Center
ETA	Estimated Time of Arrival
FRA	Federal Railroad Administration
GAO	Government Accountability Office
GOCO	Government Owned and Contractor Operated
GOGO	Government Owned and Government Operated
IEEE	Institute of Electrical and Electronics Engineers
KCS	Kansas City Southern
kW	Kilowatt
MOS	Military Occupation Specialty
MW	Megawatt
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
NS	Norfolk Southern (Railroad)
OSD	Office of the Secretary of Defense
POC	Point of Contact
SDDC	Surface Deployment and Distribution Command
SDDCTEA	Surface Deployment and Distribution Command Transportation Engineering Agency
STRACNET	Strategic Rail Corridor Network
TACOM	Tank-automotive and Armaments Command

UP	Union Pacific (Railroad)
UPS	Uninterruptable Power Supply
USACE	United States Army Corps of Engineers
V2G	Vehicle-to-Grid
WSOR	Wisconsin and Southern Railroad

Executive Summary

Introduction

Most Department of Defense (DoD) installations are dependent on standalone diesel backup generators to supply power to mission critical facilities. In order to operate these generators during extended power outages the installation must have sufficient fuel stored in integrated fuel tanks or the capacity to deliver fuel to the backup generators throughout the duration of the outage. In their response to Hurricane Florence, Fort Bragg's privatized utility responsible for maintaining their backup generators began to run out of fuel prompting an emergency procurement agreement between the utility and the local Department of Public Works (DPW).

Backup generators must be tested and maintained in order to operate effectively. With the large number of distributed generators that many installations own, maintenance can fall behind causing unexpectedly high failure rates. According to the Electric Power Research Institute (EPRI), backup generators fail 20-30% of the time, largely due to infrequent use and maintenance. In addition to high failure rates, creating n+1 redundancy for standalone generators is extremely expensive since it would require purchasing and maintaining two generators at each critical facility. High failure rates and a lack of redundancy came together during an Energy Resilience Readiness Exercise conducted at Fort Stewart when a 2.5 MW generator powering the hospital's campus failed 1 hour into the power outage. A cost-effective, flexible, centrally fueled, and easy-to-maintain solution, such as diesel-electric locomotives, to provide redundant power generation would serve the unmet gap in installation energy resilience over long term power outages.

Although diesel-electric locomotives have been demonstrated (RAF Lakenheath and Hill AFB), the viability of this approach for DoD is still unknown. For example, some locomotives produce AC power which can be readily tied to the grid. Other locomotives produce DC power which has to be inverted before connecting to the grid. Additionally, the availability of locomotives is a logistical issue. During an outage, there needs to be an operational plan to manage, connect and operate locomotives from the available fleet. Further, there is also a need to determine the economic feasibility of locomotive-based backup generation compared to traditional means such as fixed standby diesel generators.

Objective

The objective of this project is to conduct a feasibility study to evaluate the use of existing Army diesel-electric locomotives as a mobile backup electric generation solution for DoD facilities. The study investigates how diesel-electric locomotives can be implemented from technical, operational, applicability, economic, and resiliency perspectives.

Regulatory Drivers

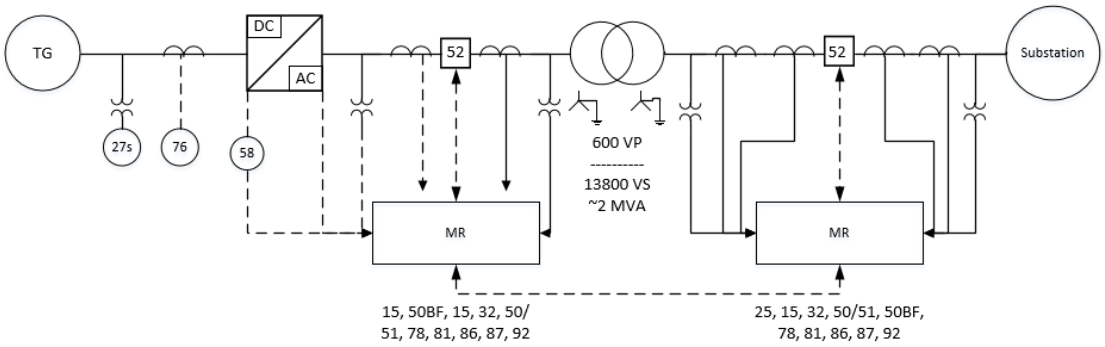
Beyond the many current DoD resilience and energy related regulatory drivers, the main policy driver for this project is Army Directive 2020-03 (INSTALLATION ENERGY AND WATER RESILIENCE POLICY, 2020) and the Office of the Secretary of Defense (OSD) memorandum *Metrics and Standards for Energy Resilience at Military Installations* (Metrics and Standards for Energy Resilience at Military Installations, 2021). These directives call for a 14-day backup power requirement for installations and a mission critical minimum availability of 99.9% per fiscal year (≤ 8.76 hours of downtime), respectfully.

Technology Description

The U.S. Army owns approximately eighty-seven diesel-electric locomotives that are ideally suited to meet emergency energy resilience demands, while still being utilized during routine mission execution. Locomotives use diesel engines to operate generators, which in turn produce electric power to drive traction motors. However, these traction motors can be decoupled from the generators, allowing the power generated to be supplied to local buildings or grids instead. There are 25 units rated at 1.5 megawatts (MW) each, 53 rated at 1.3 MW each, and 9 units rated at 2.2 MW each. In total, the Army's locomotive fleet has a combined power output capability of 123 MW. Such a mobile generation capacity could economically enhance mission resilience for installations located near rail lines. Additionally, locomotives have the capability to haul their fuel with them through utilization of railroad tank cars. Army Material Command (AMC) estimates that one 25,000-gallon tank car of diesel represents 11.5 MW-days of energy after efficiency losses. In essence, an 820 kW load could be operated for 14-days off one locomotive and one tank car, meeting the Army Directive. Depending on the locomotive power output capabilities and the load demand, one locomotive would only require hauling 1-3 full fuel tanks to more than cover the entire 14-day period, which is easily achievable and below the nominal hauling capacity for the locomotives. If additional fuel is required due to large loads or lengthier outages, more tank cars can be hauled with the locomotive or brought in as needed.

Multiple ancillary systems are required for a locomotive to be utilized as a stationary generator. First, an established docking location would be needed that has rail access adequate in length for the locomotive and its fuel supply. In theory, all equipment could be skid mounted and mobile to meet mission needs. The docking area also requires access to the local grid or specific building/process to be provided with power. Additional equipment to condition and control the power generation consists of a DC power converter, similar to those used in the wind turbine industry, step-up transformer, switchgear, and electric room/building. A fuel supply skid is also required which takes off from the bottom of the tank car to fill the locomotive fuel tanks. Depending on the facility, controls to physically isolate the local grid from the Utility may be required to mitigate concerns of exporting power. Conceptually, when the Utility is lost, installation locomotives would mobilize, collect their fuel supply, and track to the docking point onsite. Once docked, the traction motors would be decoupled and generator leads connected to an

inverter to convert the DC to AC and then the voltage would be stepped up to match grid voltage via a transformer. Sync-relays would be required to ensure locomotive-generated power matches the distribution system's frequency. Physically, this would all be accomplished within or around an electrical switchgear building located just off the locomotive docking station which would then output to the electrical distribution system via the closest substation. Figure 3 contains a reference schematic.



LEGEND			
52	AC Circuit Breaker	58	Rectification Failure Relay
MR	Multi-Function Protection Relay	50/51	Instant/Inverse Overcurrent Relay
	Voltage Transformer	76	DC Overcurrent Relay
25	Synchronizing Relay	78	Phase Angle Relay
	Current Transformer	86	Lockout Relay
15	Frequency Match Relay	87	Differential Relay
27s	DC Under Voltage Realy	81	Frequency Relay
32	Reverse Power Relay		Transformer
50BF	Breaker Failure Relay	TG	Traction Generator
92	Voltage & Power Directional Relay		

Figure 3: General Schematic of Rail-to-Grid Power Conditioning Station

ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

Leveraging the DoD's fleet of diesel-electric locomotives to supply backup electrical power for installations has the ability to improve installation energy resilience by providing backup generation assets for long-term outages. Installations that have existing backup generation will benefit from cost-effective n+1 redundancy and installations that do not have required backup generation will benefit from the dispatch of backup generation assets by rail. This technology can allow installations with temporary backup generation to extend their resilience capabilities to meet the requirement for installations to provide energy for a minimum of 14-days laid out in Army Directive 2020-03 (INSTALLATION ENERGY AND WATER RESILIENCE POLICY, 2020). Further, temporarily repurposing existing assets is expected to be significantly less expensive than owning and operating assets specifically dedicated to resilience.

Such a solution is innovative due to system mobility and utilization of existing assets owned by the U.S. Army. The concept of diesel-electric locomotives acting as generators is not new; there

are numerous references to such applications. However, these previous adaptations required disassembly and reconfiguration of the locomotive's reciprocating diesel engines and generators, rendering them immobile and dedicated as stationary generators. A rail-to-grid solution focuses on providing mobile, emergency back-up power while maintaining full use of the locomotive. This yields higher utilization of owned equipment through co-utilization of assets, decreased maintenance through having fewer pieces of equipment to maintain, and increased readiness due to mobility of the system.

Currently, while a number of military installations have small backup generators or UPS battery systems to protect small critical loads, these tend to only have enough energy to supply power for a couple hours or days. Most bases do not have the additional fuel storage capacity to run these generators much longer, and in disaster scenarios, traditional road supply lines for supplementary fuel or generators may be cut, congested, or limited. While this solution would not provide immediate power to an installation suffering an outage, critical facilities should have immediate backup generation capability or battery backup to bridge the gap between the initial outage and the arrival of the locomotive.

A drawback of this technology is that it can only be used for military installations near operating rail systems. In addition, the system is far more complex and susceptible to other risks, so the resilience it provides could be less secure than traditional backup power solutions like backup combustion generators or renewable resources with storage systems. These limitations will be explored further throughout this study.

Performance Summary

Below is the Performance Objective Table including the performance results. The results for each performance objective have been color coded green, yellow, red to denote their success in meeting the success criteria. A summary of the findings for each criterion can be seen below in the following subsections.

Table 1: Performance Objective Table

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Meet General DoD Backup Power Requirement	Days of sustained backup power provided	Fuel storage and transport capabilities; installation power requirements	≥ 14 days	≥ 14 days
Sufficient Technology Applicability	Minimum % of significant installations with access to this technology	Number of installations with access to rail that are also of significant importance to back up	≥ 30%	<< ~25-28%
Adequate response time	Total hours to return power to the installation	Locomotive and operational logistics	~~< 12 hours~~ < 8.76 hours	Possible but greatly limited without considering many other limitations
Reduced Cost Compared to Traditional Backup Power	Lifecycle Cost in Dollars	Itemized component list, cost data, location cost indexes	> 30% lower	~38% lower to >50% higher depending on circumstances
Qualitative Performance Objectives				
Enhanced Resilience Compared to Traditional Backup Power	Resilience	Average annual outage duration and other resiliency data	≥ resilience offered by a 2MW diesel generator	Comparatively Lower Net Resilience

Meet General DoD Backup Power Requirement

To better assess the acceptability of this technology as a wide-spread backup power strategy, a study was performed to determine if this technology has the capability to provide at least 14 days of backup power. Section 3.2 investigates the amount of fuel required to run a locomotive for 14 days, the amount of fuel that can be transported via a train fuel car, and the hauling capability of a locomotive. It was determined that only 1-3 fuel cars would be needed to supply enough fuel for a 14-day outage event. Since locomotives typically haul dozens of loaded train cars, this hauling capacity is trivial. As a result, this performance criterion is fully met.

Sufficient Technology Applicability

To determine the applicability of this technology, the team relied on the official 2018 Military Surface Deployment and Distribution Command Transportation Engineering Agency STRACNET report (SDDCTEA, 2018). It specified that 126 installations fit our criteria for locations of 1) having access to rail, and 2) being deemed of significant importance to be worthwhile to back up in the case of an emergency. To meet performance criteria, this technology needs to be applicable to more than 30% of DoD installations. According to the Pentagon and the Military Analysis Network, the United States has approximately 450 to 500 military installations, depending on how you classify them. Based on these numbers, this technology only applies to roughly 25-28% of installations and does not meet the 30% criterion.

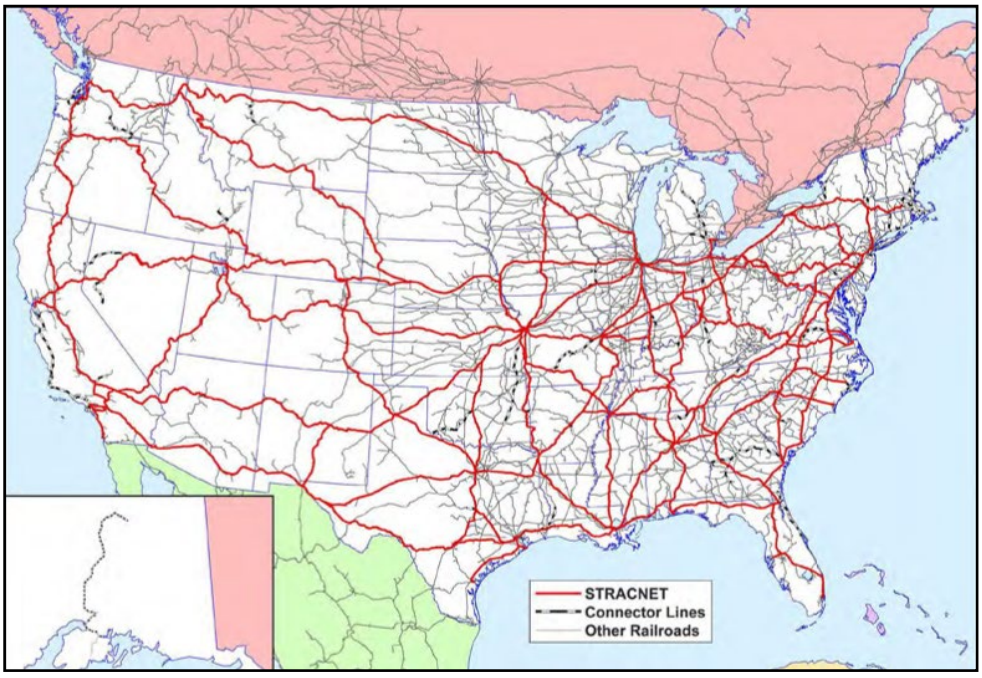


Figure 4: STRACNET, Connector Lines, and Other Railroads Map (SDDCTEA, 2018)

However, these percentages are already too optimistic. In the following section, the Adequate Response Time requirement limits applicability to areas that have relatively densely spaced installations, like in some places along the US coasts. In addition, interviews with POCs at TACOM including input from ASC, SDDC, and DOT personnel revealed that, "the majority of the installations do not have tank cars to store or transport fuel." As a result, applicable installations would need to have these capabilities at the ready, or risk falling outside of the already tight response time window by locating and making the extra trip for tank cars.

Adequate Response Time

In order to be useful to the DoD, this technology needs to return power to the affected installation quickly. However, due to the continuously-changing distributed nature of these locomotives throughout the country in comparison to any particular installation that would require backup power, determining an exact and single response time is difficult. As a result, the team decided to begin by working backwards starting with the most optimistic estimates. To meet the OSD standards outlined in Section 1.3, 99.9% uptime per fiscal year is required, or 8.76 hours of maximum response time. After estimating the fixed amount of time for all steps besides locomotive travel time, the travel distance was calculated using the taking the remaining time allotment and dividing by the average military locomotive speed of 22 mph outlined in the *Logistics Handbook for Strategic Mobility Planning* (SDDCTEA, 2011), to provide a maximum travel distance of 126.5 miles. For perspective, this is the rough distance from Champaign, IL to Chicago, IL or Los Angeles to San Diego, CA.

This optimistic distance, along with the number applicable installations significantly reduces the applicability of the technology. The only applicable areas are those with dense military installation spacing, like some areas along the US coasts. This spacing also heightens the risks of concurrent outages, lack of locomotive and fuel availability, and route blockages. This distance also assumes flawless coordination between installations, electricians, multiple sets of rail operators, government and civilian businesses, an unused and waiting locomotive with all the required equipment, and no damage to the railroad tracks, all during a likely disaster. Altogether, while response time may be possible under optimistic scenarios it greatly limits its applicability without considering many likely real-world limitations. Given the high degree of variables between to conditions and installation specifics this technology only partially meets this requirement.

Reduced Cost Compared to Traditional Backup Power Scenario

To better assess the acceptability of this technology as a wide-spread backup power strategy, an economic analysis was performed. The study compared the costs of the rail-to-grid scenario to a traditional backup power scenario of installing a traditional 2MW diesel generator on the

installation. For both the rail-to-grid and the 2MW generator financial models, the costs were split into four major categories: Initial Coordination Costs, Initial Capital Costs, Reoccurring Training and Maintenance Costs, and Scenario Costs. The source for this cost data was mainly Gordian's RSMeans (Year 2021), which is North America's leading construction estimating database for decades. Where RSMeans did not readily have data, the team was looking for, industry surveys were performed and other authoritative sources were utilized like the Institute of Electrical and Electronics Engineers (IEEE) and the Energy Information Administration (EIA). This data was then then input into the National Institute of Standards and Technology's (NIST) Building Life Cycle Cost (BLCC) software and run for 10- and 30-year periods. It was assumed no equipment replacement within 30 years, one outage per year, and a 3% discount rate.

To ascertain a better estimate on real-world applicability, the team chose three potential locations from the earlier list of applicable installations. The sites were chosen primarily to represent different regions within the United States and their unique set of cost factors. As a result, the team chose Beale AFB in California for a west coast example, Fort Lee in Virginia for an east coast example, and Camp Shelby in Mississippi for a gulf location. Beale AFB has the highest cost of living index, followed by Ft. Lee, with Camp Shelby having the lowest cost of living. For each of these three locations, local material, labor, and equipment cost factors were acquired from RSMeans 2021 Location Factor indices, local sales taxes were researched, and site factors were calculated via Google Earth. Since there was a large tradeoff between including the high cost of black start drills in exchange for the desired higher reliability of the rail-to-grid scenario, the team included a rail-to-grid scenario both with and without the cost of the black start drills for comparison.

Table 3: 10-Year Scenario Comparison

Scenario	**Camp Beale, CA**	**Fort Lee, VA**	**Camp Shelby, MS**
Rail-to-Grid W/ Black start Drills	$15,862,816	$8,863,877	$7,167,395
Rail-to-Grid W/O Black start Drills	$12,112,816	$5,113,877	$3,417,395
2MW Diesel Generator	$6,755,816	$5,617,665	$5,202,901

Table 4: 30-Year Scenario Comparison

Scenario	Camp Beale, CA	Fort Lee, VA	Camp Shelby, MS
Rail-to-Grid W/ Black start Drills	$37,056,111	$22,584,206	$18,041,128
Rail-to-Grid W/O Black start Drills	$25,806,111	$11,334,206	$6,791,128
2MW Diesel Generator	$12,757,996	$10,765,125	$10,004,361

In its essence, this cost comparison is a tradeoff between capital construction costs and labor costs. The rail-to-grid scenario should typically require less initial capital investments in exchange for a higher reoccurring labor costs every year in training, drills, and operation. Consequently, a location performed better if their location cost factors were relatively low for labor like Camp Shelby, MS in contrast to Beale AFB in California. In addition to the higher cost factor index, Beale AFB had a significantly higher cost due to significantly longer distance to connect electrical lines from near the tracks to the substation (~14,200 feet at Beale AFB compared to ~8,900 feet at Ft. Lee and Camp Shelby) and the significantly higher cost of trenching on the West Coast. Based on the results, the only instance of the rail-to-grid scenario being significantly cheaper than the traditional backup power scenario (>30%) is at the location with the cheapest cost factor and without the cost of black start drills factored in. This suggests that rail-to-grid may be economically viable but only under the correct circumstances.

Enhanced Resilience Compared to Traditional Backup Power Scenario

After doing more research on the rail-to-grid strategy, the team felt it important to add an additional section on resilience. Regardless of how optimistic the current set of assumptions are that are required to make the project potentially feasible, some of the underlying assumptions were found to be lackluster as well.

Primarily, it was reasoned that the strategy would be too slow to remedy most small to medium sized outages and unreliable in most cases of large, long-term scenarios. These larger outages could likewise require the use of these locomotive assets for other important duties like transportation of food, supplies, or military people and equipment. In addition, a 2MW generator comes with additional benefits of allowing peak shaving and demand response programs, selectable equipment siting for added efficiencies. Furthermore, the strategy increases complexity which fundamentally undermines resilience in mechanical systems according to Complexity Theory.

While resilience is notoriously difficult to quantify, and the team doesn't attempt to do so here, it's safe to say that the rail-to-grid scenario generally does not tend to increase resilience over the traditional 2MW generator strategy unless that generator has already failed. Even then there are so many complexities and other variables that it makes it risky to fall back on in a disaster scenario.

Implementation Issues

The rail-to-grid backup power solution did not pass the performance assessment. While the technology is technically feasible, under current real-world conditions it performs worse from operational, applicability, most economic, and resilience standpoints as compared to the traditional backup power benchmark. In addition to these, it also relies on the following list of significant assumptions:

- On-call personnel will be available 24/7 in the event of an emergency
- Locomotive will be available within ~126.5 miles
- Fuel cars will be available at or near that location
- No other outages occurred within one fiscal year
- Commercial crews will be available during a time of emergency
- Commercial crews will be prompt during a time of emergency
- Rail lines are operational before the emergency scenario
- Rail lines are not damaged during/after the emergency scenario
- Radio communications between government and commercial operators can be established and operate during grid outage
- No concurrent outages from the locomotive sending location
- Contracts can be made with all national and unique local parties across 3 different business models
- New contracts won't increase nominal rates
- Routine black start drills are not required
- A microgrid already exists

Nearly any one of these substantial underlying assumptions could metaphorically derail this technology. As a result, the team would not recommend this technology for a common backup power strategy.

To be fair, it could be useful for niche scenarios or in the instance that existing backup power solutions fail during an emergency like the case study from Montreal, Canada. The most reliable application for this technology would be if a locomotive is reliably stationed at an installation and is already onsite with fuel during an outage. However, this largely defeats this study's underlying value proposition of "dispatchable" or "mobile" backup power.

Overall, the last couple years have demonstrated the importance of investing in reliable infrastructure without complex supply chains and interdependencies when it matters most.

Consequently, the following motto holds true: “Let us be efficient where we can, and effective where we must.” And mission critical backup power is a must.

1.0 INTRODUCTION

This feasibility study investigates the innovative concept of leveraging existing mobile DoD locomotive assets to provide backup power to installations in emergency scenarios by exploring the technology's technical, operational, applicability, and resilience aspects compared to the traditional backup power scenario of a fixed standby 2MW diesel generator.

1.1 Background

Most Department of Defense (DoD) installations are dependent on standalone diesel backup generators to supply power to mission critical facilities. In order to operate these generators during extended power outages the installation must have sufficient fuel stored in integrated fuel tanks or the capacity to deliver fuel to the backup generators throughout the duration of the outage. In their response to Hurricane Florence, Fort Bragg's privatized utility responsible for maintaining their backup generators began to run out of fuel prompting an emergency procurement agreement between the utility and the local Department of Public Works (DPW).

Backup generators must be tested and maintained in order to operate effectively. With the large number of distributed generators that many installations own, maintenance can fall behind causing unexpectedly high failure rates. According to the Electric Power Research Institute (EPRI), backup generators fail 20-30% of the time, largely due to infrequent use and maintenance. In addition to high failure rates, creating n+1 redundancy for standalone generators is extremely expensive since it would require purchasing and maintaining two generators at each critical facility. High failure rates and a lack of redundancy came together during an Energy Resilience Readiness Exercise conducted at Fort Stewart when a 2.5 MW generator powering the hospital's campus failed 1 hour into the power outage. A cost-effective, flexible, centrally fueled, and easy-to-maintain solution, such as diesel-electric locomotives, to provide redundant power generation would serve the unmet gap in installation energy resilience over long term power outages.

Although diesel-electric locomotives have been demonstrated (RAF Lakenheath and Hill AFB), the viability of this approach for DoD is still unknown. For example, some locomotives produce AC power which can be readily tied to the grid. Other locomotives produce DC power which has to be inverted before connecting to the grid. Additionally, the availability of locomotives is a logistical issue. During an outage, there needs to be an operational plan to manage, connect and operate locomotives from the available fleet. Further, there is also a need to determine the economic feasibility of locomotive-based backup generation compared to traditional means such as fixed standby diesel generators.

1.2 Objective

The objective of this project is to conduct a feasibility study to evaluate the use of existing Army diesel-electric locomotives as a mobile backup electric generation solution for DoD facilities. The study investigates how diesel-electric locomotives can be implemented from technical, operational, applicability, economic, and resiliency perspectives.

1.3 Regulatory Drivers

Beyond the many current DoD resilience and energy related regulatory drivers, the main policy driver for this project is Army Directive 2020-03 (INSTALLATION ENERGY AND WATER RESILIENCE POLICY, 2020). This directive outlines, "the Army will sustain critical missions by being capable of withstanding an extended utility outage for a duration set by the senior commander or higher headquarters based on timeframes to accomplish, curtail, or relocate the critical mission(s). When the duration of the critical mission(s) has not been stipulated, the Army will plan to sustain energy and water for a minimum of 14 days." As a result, Army installations have a higher requirement for continuous backup energy needs.

In addition, since the feasibility study was proposed the Office of the Secretary of Defense (OSD) released the memorandum *Metrics and Standards for Energy Resilience at Military Installations* (Metrics and Standards for Energy Resilience at Military Installations, 2021). These standards dictate "DoD Components shall, by the end of fiscal year 2030, provide that 100 percent of the energy load required to maintain the critical missions of each DoD installation have a minimum level of availability of at least 99.9 percent per fiscal year, or higher availability as this memorandum provides." In relevance to this feasibility study, a 99.9% uptime requires an update of this study's original performance objectives. As a result, the allowable dispatch time for this technology should be decreased from 12 hours to less than 8.76 hours to fall within these requirements.

2.0 PERFORMANCE OBJECTIVES

To determine if this technology can be considered as an acceptable backup power solution, the team evaluated the technology to determine if it is reasonably feasible, suitable, and complete under real-world scenarios. Table 1 below illustrates the grading criteria. Due to new guidance on adequate response times discussed in Section 1.3, we modified the Response Time success criteria from below 12 hours to below 8.76 hours. Also, the qualitative performance objective "Enhanced Resilience Compared to Traditional Backup Power" was added for a more complete assessment. The results will be discussed throughout the study.

Table 1: Performance Objective Table

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Meet General DoD Backup Power Requirement	Days of sustained backup power provided	Fuel storage and transport capabilities; installation power requirements	≥ 14 days	≥ 14 days
Sufficient Technology Applicability	Minimum % of significant installations with access to this technology	Number of installations with access to rail that are also of significant importance to back up	≥ 30%	<< ~25-28%
Adequate Response Time	Total hours to return power to the installation	Locomotive and operational logistics	~~< 12 hours~~ < 8.76 hours	Possible but greatly limited without considering many other limitations
Reduced Cost Compared to Traditional Backup Power	Lifecycle Cost in Dollars	Itemized component list, cost data, location cost indexes	> 30% lower	~38% lower to >50% higher depending on circumstances
Qualitative Performance Objectives				
Enhanced Resilience Compared to Traditional Backup Power	Resilience	Average annual outage duration and other resiliency data	≥ resilience offered by a 2MW diesel generator	Comparatively Lower Net Resilience

3.0 TECHNOLOGY DESCRIPTION

3.1 Literature Review

While a rail-to-grid strategy is an innovative idea, vehicle-to-grid (V2G) technology is not entirely new. There have been numerous successful small-scale projects in the world and the United States. USACE ERDC-CERL was part of the team to demonstrate a 1.5MW fuel cell locomotive in Los Angeles California in 2009/2010 which demonstrated V2G capabilities when it provided backup power to a repair and rebuild shop at Hill Air Force Base, Utah (Miller, 2016). More recently in 2021, Protera installed a bi-directional charging system into a bus in Beverly, Massachusetts that delivered power to the grid for 50 hours (Motavalli, 2021). In July of 2022 San Diego Gas & Electric connected eight buses to the grid via bi-directional chargers and they're planning for more in the future (Edison Electric Institute, 2022). In fact, the Ford F-150 and the Nissan Leaf recently went public with their abilities to perform a form of V2G operation as well.

Figure 1: Melanie Johnson (USACE ERDC-CERL) inspecting the hybrid fuel cell locomotive during the public demonstration at BNSF Commerce during 19-20 November 2009 (Miller, 2016)

Perhaps best example of V2G for this context, and more specifically the rail-to-grid strategy, is a case in Montreal, Canada in January of 1998. That year an especially bad ice storm knocked over electrical transmission towers, leaving the town of Boucherville without power during the storm. As a result, the mayor requested and received two diesel-electric locomotives from the Canadian National Railway. While they weren't initially prepared to dock the locomotives or run electrical lines from the tracks to the local city hall and high school emergency shelter, they deployed a crane to lift the locomotives off the track and proceeded to drive the locomotives down street, carving deep ruts in the asphalt. While not ideal, the town successfully kept the lights on for its residents

for several days during and after the storm (Liszewski, 2021). Clearly these examples demonstrate the feasibility, and the growing buildup of V2G and rail-to-grid technologies.

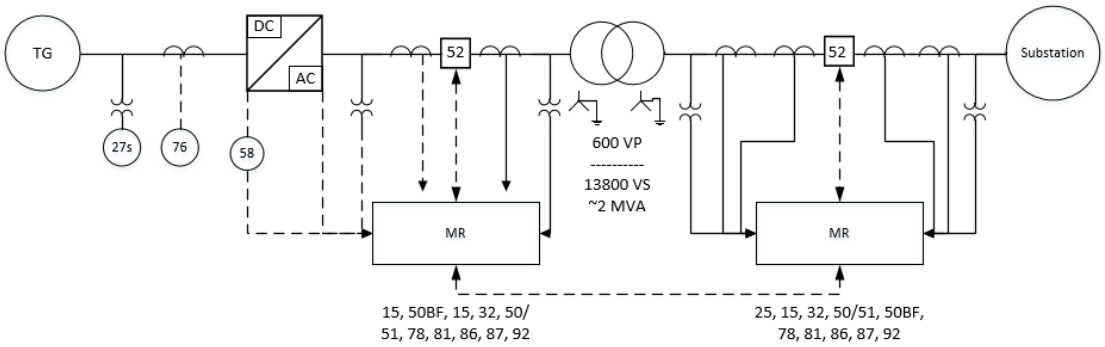
Figure 2: CN M-240 locomotive serving as a generator in January 1998, via YouTube

3.2 TECHNOLOGY OVERVIEW

The U.S. Army owns approximately eighty-seven diesel-electric locomotives that are ideally suited to meet emergency energy resilience demands, while still being utilized during routine mission execution. Locomotives use diesel engines to operate generators, which in turn produce electric power to drive traction motors. However, these traction motors can be decoupled from the generators, allowing the power generated to be supplied to local buildings or grids instead. There are 25 units rated at 1.5 megawatts (MW) each, 53 rated at 1.3 MW each, and 9 units rated at 2.2 MW each. In total, the Army's locomotive fleet has a combined power output capability of 123 MW. Such a mobile generation capacity could economically enhance mission resilience for installations located near rail lines. Additionally, locomotives have the capability to haul their fuel with them through utilization of railroad tank cars. Army Material Command (AMC) estimates that one 25,000-gallon tank car of diesel represents 11.5 MW-days of energy after efficiency losses. In essence, an 820-kW load could be operated for 14-days off one locomotive and one tank car, meeting the Army Directive. Depending on the locomotive power output capabilities and the load demand, one locomotive would only require hauling 1-3 full fuel tanks to more than cover the entire 14-day period, which is easily achievable and below the nominal hauling capacity for the locomotives. If additional fuel is required due to large loads or lengthier outages, more tank cars can be hauled with the locomotive or brought in as needed.

Multiple ancillary systems are required for a locomotive to be utilized as a stationary generator. First, an established docking location would be needed that has rail access adequate in length for the locomotive and its fuel supply. In theory, all equipment could be skid mounted and mobile to meet mission needs. The docking area also requires access to the local grid or specific

building/process to be provided with power. Additional equipment to condition and control the power generation consists of a DC power converter, similar to those used in the wind turbine industry, step-up transformer, switchgear, and electric room/building. A fuel supply skid is also required which takes off from the bottom of the tank car to fill the locomotive fuel tanks. Depending on the facility, controls to physically isolate the local grid from the Utility may be required to mitigate concerns of exporting power. Conceptually, when the Utility is lost, installation locomotives would mobilize, collect their fuel supply, and track to the docking point onsite. Once docked, the traction motors would be decoupled and generator leads connected to an inverter to convert the DC to AC and then the voltage would be stepped up to match grid voltage via a transformer. Sync-relays would be required to ensure locomotive-generated power matches the distribution system's frequency. Physically, this would all be accomplished within or around an electrical switchgear building located just off the locomotive docking station which would then output to the electrical distribution system via the closest substation. Figure 3 contains a reference schematic.



LEGEND				
52	AC Circuit Breaker		58	Rectification Failure Relay
MR	Multi-Function Protection Relay		50/51	Instant/Inverse Overcurrent Relay
	Voltage Transformer		76	DC Overcurrent Relay
25	Synchronizing Relay		78	Phase Angle Relay
	Current Transformer		86	Lockout Relay
15	Frequency Match Relay		87	Differential Relay
27s	DC Under Voltage Realy		81	Frequency Relay
32	Reverse Power Relay			Transformer
50BF	Breaker Failure Relay		TG	Traction Generator
92	Voltage & Power Directional Relay			

Figure 3: General Schematic of Rail-to-Grid Power Conditioning Station

3.3 CONTROLS

To export the power to the grid, the electrical voltage, phase, and frequency need to be controlled precisely. The easiest way to do this is to have the rail-to-grid technology provide the master signal to the grid, since it is comparatively the "dumbest" piece of equipment because the locomotive wasn't specially designed for this application. In this strategy, if it is desired that other distributed

generation resources (DERs) are added to the grid, it is assumed that these sources can usually accommodate the rail-to-grid technology's signals much more effectively than the reverse set-up.

To set the grid conditions, modern locomotives have the controls necessary to automatically adjust their setpoint to provide "constant speed" signals to drivetrain. This is fairly analogous to the governors built into generators constantly adjusting the generator setpoint to provide a constant output voltage, phase, and frequency with changes in load/demand. While it's feasible that locomotive controls could be done with manually as an emergency last resort depending on grid conditions, but it's highly recommended this be done with software controls.

If the rail-to-grid technology cannot act as the grid master, then significant controls and communications would need to be added to allow the locomotive drivetrain controller to more precisely receive commands from grid signals. While certainly a novel challenge, it's believed this is concretely feasible due to a growing amount of successful similar work being done across the industry for many years.

Finally, no controls strategy would be complete without the multiple breakers and synchronization relays shown in the schematic. These controls act as a second line of defense in case the generator becomes unsynchronized from the grid or if other faults occur.

3.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

Leveraging the DoD's fleet of diesel-electric locomotives to supply backup electrical power for installations has the ability to improve installation energy resilience by providing backup generation assets for long-term outages. Installations that have existing backup generation will benefit from cost-effective n+1 redundancy and installations that do not have required backup generation will benefit from the dispatch of backup generation assets by rail. This technology can allow installations with temporary backup generation to extend their resilience capabilities to meet the requirement for installations to provide energy for a minimum of 14-days laid out in Army Directive 2020-03 (INSTALLATION ENERGY AND WATER RESILIENCE POLICY, 2020). Further, temporarily repurposing existing assets is expected to be significantly less expensive than owning and operating assets specifically dedicated to resilience.

Such a solution is innovative due to system mobility and utilization of existing assets owned by the U.S. Army. The concept of diesel-electric locomotives acting as generators is not new; there are numerous references to such applications. However, these previous adaptations required disassembly and reconfiguration of the locomotive's reciprocating diesel engines and generators, rendering them immobile and dedicated as stationary generators. A rail-to-grid solution focuses on providing mobile, emergency back-up power while maintaining full use of the locomotive. This yields higher utilization of owned equipment through co-utilization of assets, decreased maintenance through having fewer pieces of equipment to maintain, and increased readiness due to mobility of the system.

Currently, while a number of military installations have small backup generators or UPS battery systems to protect small critical loads, these tend to only have enough energy to supply power for a couple hours or days. Most bases do not have the additional fuel storage capacity to run these generators much longer, and in disaster scenarios, traditional road supply lines for supplementary fuel or generators may be cut, congested, or limited. While this solution would not provide immediate power to an installation suffering an outage, critical facilities should have immediate backup generation capability or battery backup to bridge the gap between the initial outage and the arrival of the locomotive.

A drawback of this technology is that it can only be used for military installations near operating rail systems. In addition, the system is far more complex and susceptible to other risks, so the resilience it provides could be less secure than traditional backup power solutions like backup combustion generators or renewable resources with storage systems. These limitations will be explored further throughout this study.

4.0 OPERATIONAL LOGISTICS

To better assess the acceptability of this technology as a wide-spread backup power strategy, the operational logistics were investigated. To shed light on the operational logistics required for this technology, it's crucial to understanding the general railroad operational environment it would need to exist in, discussed in the next section.

4.1 General Railroad Logistics and Background

The United States rail network is made of an estimated 140,000 miles of tracks, of which the Strategic Rail Corridor Network (STRACNET) and its connector lines account for about 37,700 miles. STRACNET, seen below in Figure 4, is specific network of rail corridors that have been designated as highly important to national defense for mobilization/deployment, peacetime, and combat shipment needs. While each branch of the military relies on the STRACNET, the Army has taken over most rail work for the branches since the 1970s.

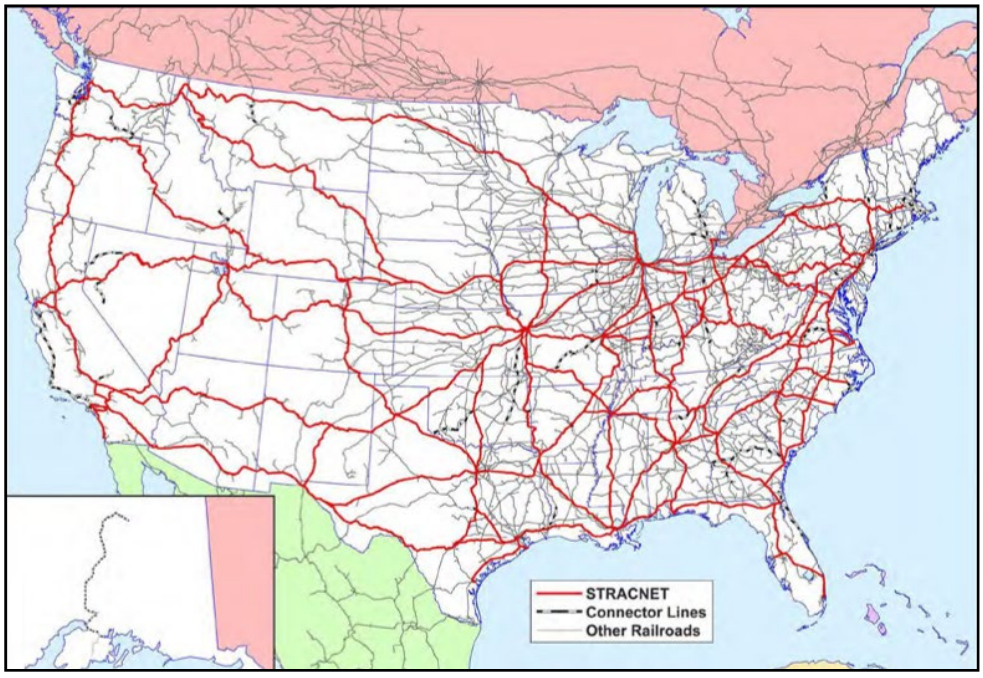


Figure 4: STRACNET, Connector Lines, and Other Railroads Map (SDDCTEA, 2018)

To fulfill operations requirements, a distinct Military Occupation Specialty (MOS) exists, designated 88U, for the Railway Operations Crewmember position as part of the Army Reserve in the Transportation Corps. However, the number of these positions shrunk by 70 percent in 2015 when

the rail units were decreased from four battalions to one in a shift to rely on the commercial sector as an effort to save money. As a result, there are only about 175 of these 88U crewmembers serving at this time, and it is implied these crews are kept fairly busy.

In addition to 88U positions for many on-post operations, the Army also depends on commercial rail carriers for off-post rail movements. This results in three main business models: government owned and government operated (GOGO); government owned and contractor operated (GOCO), and privatized (Army Installation Rail Operations: Implications of Increased Outsourcing, 2017). As a result of the different business models and unique contracts for each installation and local commercial railway, it's very difficult to precisely define a one-size-fits-all operation procedure and set of requirements for this backup power strategy. Furthermore, through government interviews and surveys, the team discovered that the radios the government uses for their rail operation function on a different network than the commercial crews. For the tight coordination required for this rail-to-grid scenario, streamlined communication between government and commercial rail crews will be required.

Army Installations by Rail Business Model

GOGO	GOCO	Privatized
Fort Hood	Fort Sill	Fort Benning
Fort Carson	Fort Bliss	Fort Drum
Joint Base Lewis-McChord	Fort Bragg	Fort Knox
Fort Leonard Wood	Fort Campbell	Fort Polk
Fort Riley	Fort Irwin	
Fort Stewart	Fort McCoy	

SOURCE: U.S. Army Audit Agency, 2017.

Figure 5: Examples of Rail Business Models By Installation (Army Installation Rail Operations: Implications of Increased Outsourcing, 2017)

This reliance on commercial crews manifests several risks that effect the reliability of this technology. Besides a well-founded list of documented safety concerns and additional hidden costs, privatization can cause delays in a rail environment which timescales for most train movements already occur on the order of days to months, not the minutes to hours required by this backup power strategy. For example, Ft. Hood rail personnel stated that "BNSF rail crews typically show up 6 to 12 hours late to pick up trains" (Army Installation Rail Operations: Implications of Increased Outsourcing, 2017). Moreover, based on SDDC rail shipment data from 2015 seen below in Figure 6, almost of one third of rail movements were late. While they were all eventually delivered within 5 days of expected arrival time, both the normal and long-term delays would be entirely insufficient for the required 8.76-hour response time required for this technology.

Rail Carrier	Total Cars Delivered	Percent Delivered On or Before Original ETA	Percent Delivered Within Two Days of Original ETA	Percent Delivered Within Four Days of Original ETA
BNSF	4,265	73	90	96
CSX	2,753	61	80	84
KCS	2,327	66	90	94
NS	2,623	62	85	90
UP	9,083	63	86	93
WSOR	68	47	47	76
Other	1,689	64	80	86
Total	**22,808**	**65**	**86**	**92**

SOURCE: SDDC rail shipment data.

NOTES: WSOR = Wisconsin & Southern Railroad; KCS = Kansas City Southern.

Figure 6: Timeliness of Rail Carriers on Fiscal Year 2015 (Army Installation Rail Operations: Implications of Increased Outsourcing, 2017)

Another potential challenge of working in the existing environment is the condition of the railroad tracks. According to the 2018 STRACNET report, "The FRA inspection of designated defense rail lines reveals that, at the time of FRA's inspection, overall the carriers maintained their lines in defense readiness condition" (SDDCTEA, 2018). However, in an August 2021 report from the Government Accountability Office (GAO), a legislative branch government agency, it was stated that while the Army has taken steps to manage rail quality control, "Army inspectors characterized about half of the Army's rail track as closed due to defects, and four of 60 installations had not met or were not scheduled to meet the 5-year ultrasonic inspection timeline standard set by the Army inspection program." (U.S. Government Accountability Office, 2021). In the case of an emergency scenario, these tracks could prove unusable for this technology to operate.

As a result, while the rail system in the United States is relatively large and capable, it is evident there are many facets that pose risks to this backup power strategy's logistic and economic feasibility given the tight requirement tolerances explained later in this study.

4.2 Rail-to-Grid Operational Procedure

Through the team's research and the help of surveys completed with key POCs, a rail-go-grid operational procedure was outlined. Survey input included POCs from the Army Sustainment Command (ASC), Surface Deployment and Distribution Command (SDDC), Tank-automotive and Armaments Command (TACOM), and the Department of Transportation (DOT). This procedure is separated into three sections: the activation procedure, sustainment procedure, and the disengage procedure.

Activation Procedure

1. Installation outage occurs
2. Installation manager contacts AMC to request backup power rail-to-grid scenario
3. AMC/rail operator determines if there is an applicable locomotive nearby that meets all criteria
4. AMC/rail operator dispatches on-call 88-U/contractor POCs and DoD/DoE HAZMAT escort in preparation. 88-Us/contractors prepare and move toward the applicable locomotive.
5. Rail operator contacts government and civilian commercial rail carrier POCs to determine if there are reported damages to the train tracks and if track switching and other critical capabilities are online. If no, then instruct them to engage.
6. Rail operator confirms with 88-Us/contractors to engage and informs installation manager
7. Installation manager contacts on-call electrician at destination to coordinate the connection of locomotive power to the switchgear building feeding the grid/substation
8. 88-Us/contractors fill fuel tanks (enough for round trip and a conservative estimate for grid electricity production), load diesel pump skid onto flatbed car, assembles and couples train cars, performs safety inspections, etc.
9. Locomotive travels to destination with DoD/DoE HAZMAT escort in a separate transport vehicle while rail operator coordinates rail movement
10. Installation manager works with on-site electrician and related POCs to prepare the local grid for staged power return under a black start scenario by disconnecting from the main electric grid and by disconnecting most loads
11. Locomotive arrives and docks
12. 88-Us/contractors disengage diesel-electric power from the drivetrain and prepare it to export power
13. Electrician connects the locomotive to the switchgear building and prepares for operation
14. Upon electrician approval, 88-Us/contractors reengage diesel-electric power
15. Electrician and related POCs oversees the export to the grid
16. Upon energizing the grid, the staged reconnecting of the local microgrid can be performed in addition to bringing any additional, on-site, synchronizable, distributed generation assets back online to help support the microgrid

Sustainment Procedure

17. 88-Us/contractors coordinate the diesel fuel pump and fuel tanks to ensure the locomotive has adequate fuel at all times
18. Rail crews are generally limited to 12-hour shifts for no more than six consecutive days. Thus, two crews can only conduct 24-hour operations for six days. For more than six days of duty, additional rail crews would need to be coordinated by the installation manager and AMC. When not working, rail crews will require TDY accommodations to include food, lodging, and possible support vehicle for travel to TDY site.

Disengage Procedure

19. Upon end of the outage, the installation prepares for a short-term loss of power by notifying power users and preparing to disconnect the locomotive power from the microgrid.
20. Electrician switches off power to the microgrid as 88-Us/contractors turn off locomotive power
21. 88-Us/contractors reconnect the diesel-electric power to the locomotive's drivetrain
22. Electrician physically disconnects the locomotive from the switchgear building
23. Electrician and related POCs reconnect the microgrid to the main electrical grid and reenergizes installation loads in stages until the system is back in its desired state
24. Rail operator contacts government and civilian commercial rail carrier POCs to coordinate the locomotive's return
25. If there is fuel being returned, the DoD/DoE HAZMAT escort will be required as well
26. Upon coordination, 88-Us/contractors prepare the locomotive for departure
27. Locomotive travels to destination with a DoD/DoE HAZMAT escort in a separate transport vehicle while rail operator coordinates rail movement
28. At destination, procedure is followed to return equipment to its original state
29. 88-Us/contractors are relieved
30. Rail operator, 88-Us/contractors, installation manager, and government and civilian commercial rail carriers coordinate the submission of bills to pay for the exercise

4.3 Rail-to-Grid Preparation Requirements

While the above procedure meaningfully outlines the steps needed during a rail-to-grid scenario, there is a significant amount of work required to facilitate these actions before they can be relied upon. The following can almost be viewed as a gap analysis. Below is a list of obstacles in the areas of overall management, electrical systems, and rail systems that need to be overcome before the scenario is realized.

Management

- Obtain approval for rail-to-grid scenarios assuming the following steps are also secured:
- Modify multiple contracts across multiple parties and their legal teams including, but not limited to: each applicable installation, AMC in coordination with SDDC, DPW Real Property (Logistics/G-4), HAZMAT (for transporting large quantities of fuel), required private railroads, any contracted rail operators, electrical utilities, and local electricians. As part of these contract modifications, streamlining of processes in emergency scenarios would be required.
    - Updating all these contracts will almost certainly result in more expensive service fees
- Establish payment procedure for all required parties. Interviewed parties did not agree if this would be done via MIPR, a centrally billed account, and/or potentially applying for FEMA funding

- If not in place, create an on-call program for AMC coordination, locomotive engineers, electricians, and other related personnel

Electrical

- Establish microgrid capability if not already done
- A study at each applicable installation to determine the actual (Mission) Requirements vs desired requirements and what those exactly are, and a staged re-energization plan developed and updated
- Construction of electrical switchgear building and related equipment at each applicable installation
- If not in place, create an on-call program for electricians and other related personnel
- Train electricians for rail-to-grid operation scenarios
- Establish and perform regular equipment maintenance procedures for new equipment
- Engage in regular drill exercises at each applicable installation. While a good practice normally, these exercises would be required to ensure adequate operation under the strict time window allowed.

Rail

- Governing documents that establish procedure and rail safety standards by the American Association of Railroads (AAR) and the Federal Railroad Administration (FRA) would need to be revised to support a rail-to-grid power scenario.
- If not in place, create an on-call program for locomotive engineers and other related personnel
- Construction at installations for rail modifications if required
- Purchase equipment for rail cars including a skid mounted diesel pump
- Establish rapid response programs- virtually all current procedures take days of notice, not hours or minutes
- Revised rail communication standards or communication protocol since local radios used for government rail coordination are not compatible with commercial railroad standards for communication with commercial railroad dispatchers. This is needed to have the ability to receive updated track conditions, and track bulletins for each commercial rail line/subdivision and for other critical operational communications.
- Ensure communication and rail equipment can be operated without immediate use of electricity in the event of an outage
- Train locomotive engineers for rail-to-grid operation scenarios
- Establish and perform regular equipment maintenance procedures
- Engage in regular drill exercises at each applicable installation. While a good practice normally, these exercises would be required to ensure adequate operation under the strict time window allowed.

While many of these obstacles can be reasonably overcome, it is not yet clear if others would be possible, such as the obstacle of having all parties agree to the requirements of this timeline.

Unfortunately, these answers are nearly impossible to determine from a feasibility study. These responses can only be acquired by working with all national and local stakeholders at each location which would require top-down authority, prioritization, and direction.

4.4 Rail-to-Grid Response Time Logistics

In order to be useful to the DoD, this technology needs to return power to the affected installation quickly. However, due to the continuously changing and distributed nature of these locomotives throughout the country in comparison to any particular installation that would require backup power, determining an exact and single response time is difficult. It should be noted that theoretical response logistics strongly rely on geographical installation applicability discussed in Section 5.1, and vice versa. As a result, the team decided to begin by working backwards starting with the most optimistic estimates.

To meet the OSD standards outlined in Section 1.3, 99.9% uptime per fiscal year is required. To meet this criterion, the permissible outage time of 0.1% of the 8760 hours in a year results in 8.76 hours of maximum response time. This is a relatively low bar since this assumes no other outages during that year, including the usual outage occurrence that happens to an installation when it returns from backup power to grid power. The following table lists the assumptions that were made for the response times for every step of the procedure outlined in Section 4.2 except for the locomotive travel time. It should be noted that these assumptions are probably optimistic, and the aforementioned processes would need to be streamlined for anything like this to occur.

Table 2: Rail-to-Grid Response Time Assumptions

Rail-to-Grid Step	**Response Time (Hours)**
Initial Activation Communication Time	.25
Rail Crew Personnel Prep Time	.5
Locomotive Preparation Time (includes locomotive inspections, loading equipment, filling and connect fuel cars, etc.)	1
Grid Connection Time Upon Arrival at Installation	.25
Total	**2 hours**

Most loaded freight trains can travel roughly 70-80 miles per hour depending on conditions. However, according to the *Logistics Handbook for Strategic Mobility Planning*, defense planners use an average speed of “22 mph” to calculate travel times for military equipment transported by unit

trains to allow for the normal amount of starting, stopping, and expected delays (SDDCTEA, 2011). Considering the aggregate required preparation and response times of approximately 2 hours, this leaves about 5.75 hours of available travel time for the locomotive. At an average of 22 mph, this leaves roughly 126.5 miles of possible travel distance. For perspective, this is the rough distance from Champaign, IL to Chicago, IL or Los Angeles to San Diego, CA.

This optimistic distance, along with the number applicable installations described in Section 5.1 significantly reduces the applicability of the technology. The only applicable areas are those with dense military installation spacing, like some areas along the US coasts. This spacing also heightens the risks of concurrent outages, lack of locomotive and fuel availability, and route blockages. This distance also assumes flawless coordination between installations, electricians, multiple sets of rail operators, government and civilian businesses, an unused and waiting locomotive with all the required equipment, and no damage to the railroad tracks, all during a likely disaster. Altogether, even this optimistic scenario looks unlikely for a significant utilization.

5.0 APPLICABILITY

To better assess the acceptability of this technology as a wide-spread backup power strategy, an applicability study was performed.

5.1 Rail-to-Grid Preparation Requirements

To determine the applicability of this technology, the team sought to compile a list of DoD installations that fit 2 main criteria: 1) installations that have access to rail, and 2) installations deemed of significant importance to be worthwhile to back up in the case of an emergency. To that end, every 5 years the Military Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA) requests the DoD (to include the Army, Navy, Air Force, Marine Corps, Defense Contract Management Agency, and Defense Logistics Agency) to update their list of military installations and activities which require rail service. Following screening of that list, the SDDCTEA and the FRA jointly review the lines for the STRACNET and connectors between STRACNET and defense installations and activities requiring rail service. As a result, in their last 2018 report they identified 126 installations and activities and their related rail lines that fit the criteria (SDDCTEA, 2018). A full list of each of these installations, broken down by state and by service, is available in Appendix B. In addition, state maps of these installations and their associated STRACNET rail lines is available in Appendix C.

To meet performance criteria, this technology needs to be applicable to more than 30% of DoD installations. According to the Pentagon and the Military Analysis Network, the United States has approximately 450 to 500 military installations, depending on how you classify them. Based on these numbers, this technology only applies to roughly 25-28% of installations and does not meet the 30% criterion.

Moreover, these percentages are already too optimistic. The optimistic “adequate response time” exercise in Section 4.4 further limits applicability to areas that have relatively densely spaced installations, like in some places along the US coasts. This spacing also heightens the risks of concurrent outages, lack of locomotive and fuel availability, and route blockages. In addition, interviews with POCs at TACOM including input from ASC, SDDC, and DOT personnel revealed that, “the majority of the installations do not have tank cars to store or transport fuel.” As a result, applicable installations would need to have these capabilities at the ready, or risk falling outside of the already tight response time window by locating and making the extra trip for tank cars. Also, Section 4.1 showed evidence on the frequency of commercial crews being late. It is entirely feasible this lateness could increase in the case of a disaster whether due to commercial priorities or physical hazards impacting the railroad. In summary, it is highly probable the applicability of this technology is far below the already insufficient 25-28% criteria.

6.0 ECONOMIC ANALYSIS

To better assess the acceptability of this technology as a wide-spread backup power strategy, an economic analysis was performed. This effort compared the costs of the rail-to-grid scenario to a traditional backup power scenario of installing a traditional 2MW diesel generator on the installation. This section describes the economic models, assumptions, and three example sites used for this analysis.

Before discussing the methods and model, the team wanted to include a word of discretion. The global pandemic, supply chain roadblocks, geopolitical conflict, and inflation effecting the world for the last couple of years has made the life of a cost engineer, and the data they rely on, challenging. Furthermore, authoritative financial experts are at odds regarding predictions of where many of these trends will go in the next several years. While the team relied on authoritative data sources like RSMeans and took precautions to ensure reliability of the data, the team would like to caution the reader and recommend using slightly larger error bars than usual when considering these cost estimates.

6.1 Economic Models

For both the rail-to-grid and the 2MW generator financial models, the costs were split into four major categories: Initial Coordination Costs, Initial Capital Costs, Reoccurring Training and Maintenance Costs, and Scenario Costs. The source for this cost data was mainly Gordian's RSMeans (Year 2021), which is North America's leading construction estimating database for decades. Where RSMeans did not readily have data, the team was looking for, industry surveys were performed and other authoritative sources were utilized like the Institute of Electrical and Electronics Engineers (IEEE) and the Energy Information Administration (EIA). This data was then then input into the National Institute of Standards and Technology's (NIST) Building Life Cycle Cost (BLCC) software and run for 10- and 30-year periods. It was assumed no equipment replacement within 30 years, one outage per year, and a 3% discount rate.

The 2MW Generator scenario was fairly straightforward. The Initial Capital Costs mainly included the cost of the 2MW generator, the switchgear building, the switchgear, a 35,000-gallon diesel storage tank, power line installation, and the miscellaneous electrical wiring, switches, relays, and controls. For the Initial Coordination Costs, it was assumed a microgrid and black start strategy are existing components. This was done because these components are required for both scenarios and because the cost of a microgrid is so location specific it is beyond the scope of this project. It was also assumed that operation of a diesel generator is common enough where it could mostly be fit under existing electrical contracts with small modification. Reoccurring Training and Maintenance Costs included the cost of yearly electrician training for the generator's use and the additional maintenance costs required for this equipment. Finally, the Scenario Costs factored the costs of

operation in an outage scenario and the fuel cost required for a 14-day outage. A more detailed list of these items can be found in the input cost tables in Appendix E.

The rail-to-grid scenario was slightly more complex. The Initial Capital Costs included the cost of the switchgear building and connections, switchboard, inverter, transformer, switchgear, a skid-mounted diesel fuel pump for the locomotive, any extension of railroad tracks required, power line installation, and the miscellaneous electrical wiring, switches, relays, and controls. As discussed, under the Initial Coordination Costs, it was assumed a microgrid and black start strategy are existing components. However, this section also includes a large cost required for modifying contracts and regulations across various groups involved including but not limited to American Association of Railroads (AAR), the Federal Railroad Administration (FRA), Army Materiel Command (AMC), Surface Deployment and Distribution Command (SDDC), Department of Public Works (DPW), Department of Transportation (DOT), HAZMAT, local electricians, local railroads, and others. Naturally, this would be a massive undertaking. This cost category also includes a section for establishing a repayment procedure to compensate required parties after a rail-to-grid scenario. Reoccurring Training and Maintenance Costs include yearly training for rail and electrician operators, additional yearly maintenance for the extra equipment, and the cost of yearly practice drills. Given the importance of backup power, the very strict timeline required, and the significant change to normal operating procedures for many of the involved groups, it was deemed necessary that yearly drills will be required to have a degree of reliability of scenario success. Finally, the Scenario Costs include the labor and TDY costs for AMC management, electricians, rail crews, a required HAZMAT escort, and the cost of diesel fuel for a 14-day outage. A more detailed list of these items can be found in the input cost tables in Appendix E.

6.2 Economic Sites

To get a better estimate on real-world applicability, the team chose three potential locations from the earlier list of applicable installations. The sites were chosen primarily to represent different regions within the United States and their unique set of cost factors. As a result, the team chose Beale AFB in California for a west coast example, Fort Lee in Virginia for an east coast example, and Camp Shelby in Mississippi for a gulf location. Beale AFB has the highest cost of living index, followed by Ft. Lee, with Camp Shelby having the lowest cost of living. For each of these three locations, local material, labor, and equipment cost factors were acquired from RSMeans 2021 Location Factor indices and site factors were calculated via Google Earth. Local sales taxes were also included. For these site factors, the team calculated the smallest distance between applicable rail docking locations and the nearest substation where power could be delivered. Where required to prevent the blockage the railroads ensure its usability during outage operation, the addition of small segments of railroad were also estimated. These unique locations costs were included in the life cycle cost software. For more details on the siting for the three potential locations and their specific requirements, see the figures below.

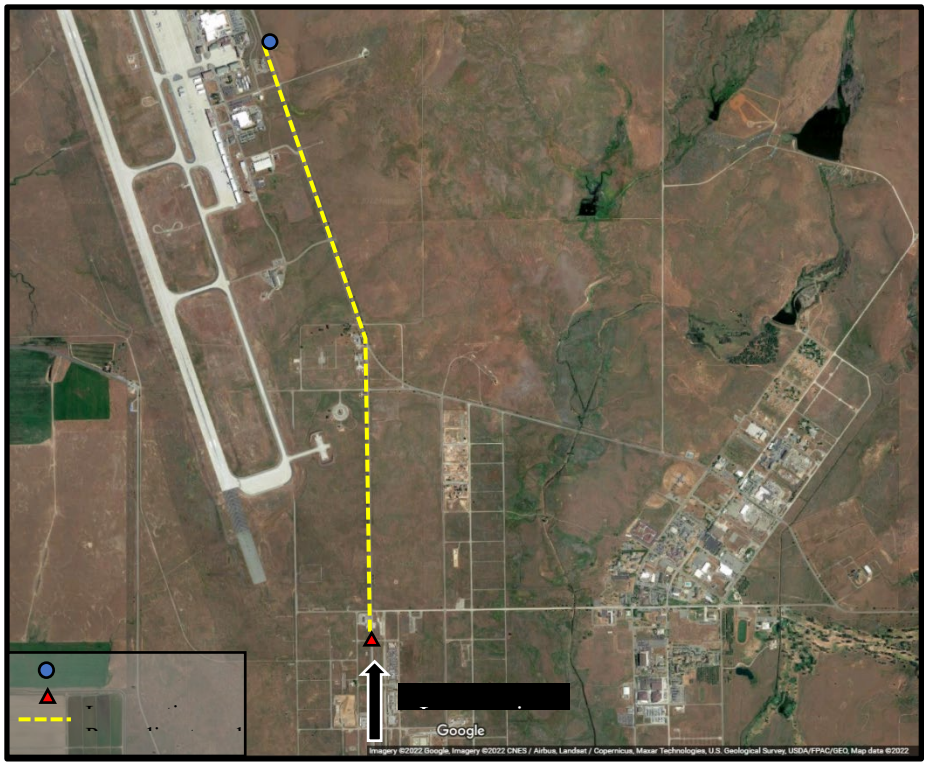


Figure 7: Beale AFB, CA Rail-to-Grid Site Assumptions

Figure 8: Fort Lee, VA Rail-to-Grid Site Assumptions

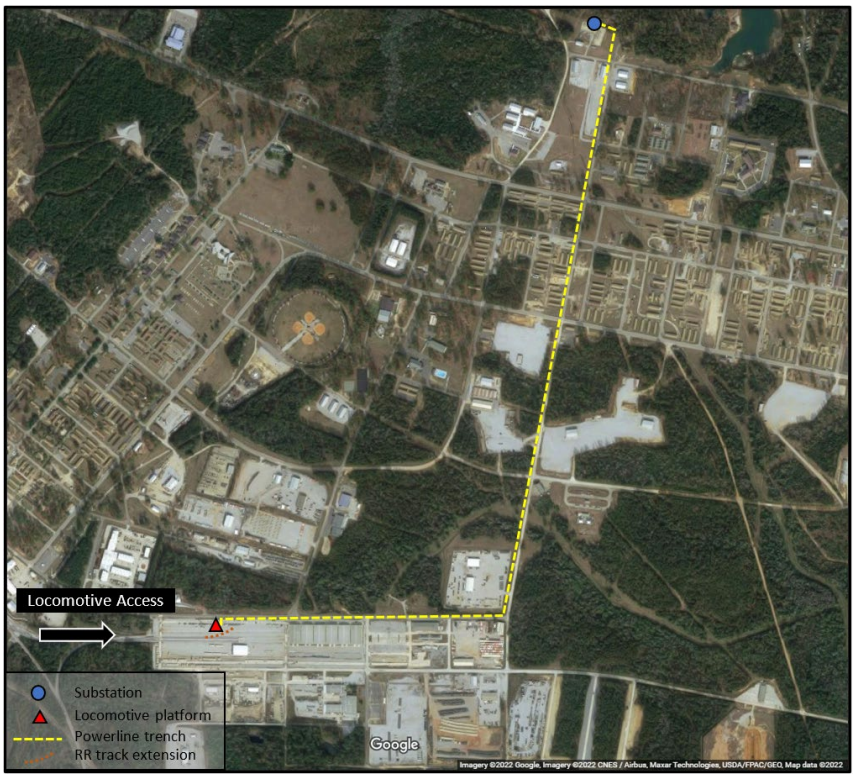


Figure 9: Camp Shelby, MS Rail-to-Grid Site Assumptions

6.3 Economic Analysis Results

Below are the results from the economic analysis. For the rail-to-grid scenario without black start drills, the simple cost of the black start drills multiplied by the number of scenario years was subtracted from the original "rail-to-grid with black start drills" result. This was done because the increasing cost of inflation was assumed to nullify the enhanced efficiency of performing black starts gained over time. For more details on the outputs of the economic analysis, see Appendix E.

Table 3: 10-Year Scenario Comparison

Scenario	Camp Beale, CA	Fort Lee, VA	Camp Shelby, MS
Rail-to-Grid W/ Black start Drills	$15,862,816	$8,863,877	$7,167,395
Rail-to-Grid W/O Black start Drills	$12,112,816	$5,113,877	$3,417,395
2MW Diesel Generator	$6,755,816	$5,617,665	$5,202,901

Table 4: 30-Year Scenario Comparison

Scenario	Camp Beale, CA	Fort Lee, VA	Camp Shelby, MS
Rail-to-Grid W/ Black start Drills	$37,056,111	$22,584,206	$18,041,128
Rail-to-Grid W/O Black start Drills	$25,806,111	$11,334,206	$6,791,128
2MW Diesel Generator	$12,757,996	$10,765,125	$10,004,361

6.4 Economic Analysis Discussion

In its essence, this cost comparison is a tradeoff between capital construction costs and labor costs. The rail-to-grid scenario should typically require less initial capital investments in exchange for a higher reoccurring labor costs every year in training, drills, and operation. Consequently, a location performed better if their location cost factors were relatively low for labor like Camp Shelby, MS in contrast to Beale AFB in California. In addition to the higher cost factor index, Beale AFB had a significantly higher cost due to significantly longer distance to connect electrical lines from near the tracks to the substation (~14,200 feet at Beale AFB compared to ~8,900 feet at Ft. Lee and Camp Shelby) and the significantly higher cost of trenching on the West Coast.

As seen in the tables, the team decided to run the numbers both with and without the assumed cost of doing a black start drill every year. Given the strict timeline of events, the difference of this work compared to normal operation, the high degree of required coordination, and a variety of uncertainties, a yearly drill, like a fire drill, was assumed important to the feasibility of the technology. However, at an average cost of $375k per data from by Robert McMahon, assistant secretary of defense for sustainment, who has done at least four of these exercises recently, it can't be ignored that it is a noteworthy cost. While the DoD has begun to mandate these black start exercises become more routine, it's not clear how routine they will become. As a result, the team included a rail-to-grid scenario without the cost of the black start drills for comparison.

Evidently, the only instance of the rail-to-grid scenario being significantly cheaper than the traditional backup power scenario (>30%) is at the location with the cheapest cost factor and without the cost of black start drills factored in. This suggests that rail-to-grid may be economically viable but only under the correct circumstances.

7.0 RESILIENCE

After doing more research on the rail-to-grid strategy, the team felt it important to add an additional section on resilience. Regardless of how optimistic the current set of assumptions are that are required to make the project potentially feasible, some of the underlying assumptions were found to be lackluster as well.

The simplest investigation suggests that even if the strategy should work, comparatively it doesn't have much resilience benefit anyway. In both small and medium outage scenarios, where you have outages ranging from minutes to a few hours, this strategy does not increase resilience because the locomotives cannot respond quick enough. According to the U.S. Energy Information Administration (EIA), even major outages are repaired in less than 6 hours on average as shown in Figure 10. In the unlikely event of large scale, multi-day outage scenarios, the installation still requires hours of energy storage to keep the installation powered. Even if this was deemed acceptable, large-scale events are usually attributable to conditions like massive natural disasters or war, suggesting a high likelihood of damage to rail systems and/or electrical grids as well, leaving this scenario ineffective. We may also depend on these scarce locomotive assets to ship equipment, people, or other critical supplies. In these scenarios, it's better to have local generators to minimize points of failure.

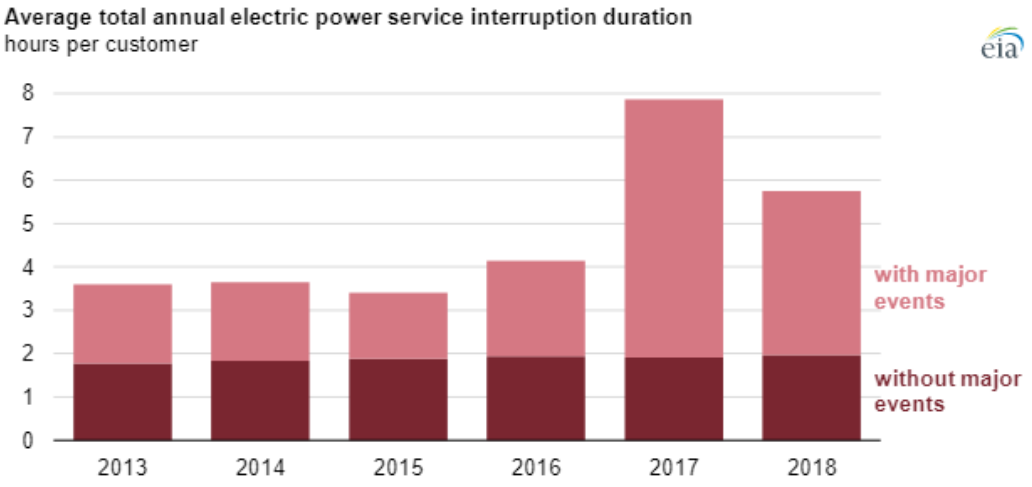


Figure 10: EIA Average Annual Power Service Interruption Duration (U.S. Energy Information Administration, 2020)

Local generator assets have many supplementary advantages. In addition to the significantly faster response time, they can regularly be used for peak shaving or demand response programs to save the installation money. From a siting perspective, the installation can better choose where to install the generators to be closer to areas or other generating assets that make them easier and more efficient to service, control, and operate. While lack of maintenance on generators can still cause higher failure rates, similar maintenance is required for locomotives and the associated equipment to run them. Likewise, while one could argue that maintenance on 87 locomotives is easier/cheaper than

generators on every military installation, the number of locomotives requiring routine maintenance is on par or higher than the total number of potentially applicable installations determined earlier in this study.

Finally, the rail-to-grid scenario introduces a significant amount of complexity. Complexity Theory states that as manufactured systems become more complicated in number of components, number of parties, communication layers, etc. their resilience is reduced without an increase in redundancy. Worse, complexity increases exponentially in emergency situations. While this feasibility study was originally assigned several years ago, the events of the past few years during worldwide pandemics, supply chain disruptions, and more have been a perfect illustration of the dangers of relying on complex, external, interconnected systems. Complexity is the enemy of resilience especially in systems that embody tightly coupled interdependencies and increased the risk from single points of failure.

While resilience is notoriously difficult to quantify, and the team doesn't attempt to do so here, it's safe to say that the rail-to-grid scenario generally does not tend to increase resilience over the traditional 2MW generator route unless that generator has already failed. Even then there are so many complexities and other variables that it makes it risky to fall back on in a disaster scenario.

8.0 PERFORMANCE ASSESSMENT

Below is reminder of Performance Objective Table from Section 2 including the performance results. The results for each performance objective have been color coded green, yellow, red to denote their success in meeting the success criteria. A summary of the findings for each criterion can be seen below in the following subsections.

Table 1: Performance Objective Table

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Meet General DoD Backup Power Requirement	Days of sustained backup power provided	Fuel storage and transport capabilities; installation power requirements	≥ 14 days	≥ 14 days
Sufficient Technology Applicability	Minimum % of significant installations with access to this technology	Number of installations with access to rail that are also of significant importance to back up	≥ 30%	<< ~25-28%
Adequate response time	Total hours to return power to the installation	Locomotive and operational logistics	~~< 12 hours~~ < 8.76 hours	Possible but greatly limited without considering many other limitations
Reduced Cost Compared to Traditional Backup Power	Lifecycle Cost in Dollars	Itemized component list, cost data, location cost indexes	> 30% lower	~38% lower to >50% higher depending on circumstances
Qualitative Performance Objectives				
Enhanced Resilience Compared to Traditional Backup Power	Resilience	Average annual outage duration and other resiliency data	≥ resilience offered by a 2MW diesel generator	Comparatively Lower Net Resilience

8.1 Meet General DoD Backup Power Requirement

To better assess the acceptability of this technology as a wide-spread backup power strategy, a study was performed to determine if this technology has the capability to provide at least 14 days of backup power. Section 3.2 investigates the amount of fuel required to run a locomotive for 14 days, the amount of fuel that can be transported via a train fuel car, and the hauling capability of a locomotive. It was determined that only 1-3 fuel cars would be needed to supply enough fuel for a 14-day outage event. Since locomotives typically haul dozens of loaded train cars, this hauling capacity is trivial. As a result, this performance criterion is fully met.

8.2 Sufficient Technology Applicability

To determine the applicability of this technology, the team relied on the official Military Surface Deployment and Distribution Command Transportation Engineering Agency STRACNET report. It specified that 126 installations fit our criteria for locations of 1) having access to rail, and 2) being deemed of significant importance to be worthwhile to back up in the case of an emergency. To meet performance criteria, this technology needs to be applicable to more than 30% of DoD installations. According to the Pentagon and the Military Analysis Network, the United States has approximately 450 to 500 military installations, depending on how you classify them. Based on these numbers, this technology only applies to roughly 25-28% of installations and does not meet the 30% criterion.

However, these percentages are already too optimistic. In the following section, Section 8.3, the Adequate Response Time requirement limits applicability to areas that have relatively densely spaced installations, like in some places along the US coasts. In addition, interviews with POCs at TACOM including input from ASC, SDDC, and DOT personnel revealed that, “the majority of the installations do not have tank cars to store or transport fuel.” As a result, applicable installations would need to have these capabilities at the ready, or risk falling outside of the already tight response time window by locating and making the extra trip for tank cars.

8.3 Adequate Response Time

In order to be useful to the DoD, this technology needs to return power to the affected installation quickly. However, due to the continuously-changing distributed nature of these locomotives throughout the country in comparison to any particular installation that would require backup power, determining an exact and single response time is difficult. As a result, the team decided to begin by working backwards starting with the most optimistic estimates. To meet the OSD standards outlined in Section 1.3, 99.9% uptime per fiscal year is required, or 8.76 hours of maximum response time. After estimating the fixed amount of time for all steps besides locomotive travel time, the travel distance was calculated using the taking the remaining time allotment and dividing by the average

military locomotive speed of 22 mph outlined in the *Logistics Handbook for Strategic Mobility Planning*, to provide a maximum travel distance of 126.5 miles. For perspective, this is the rough distance from Champaign, IL to Chicago, IL or Los Angeles to San Diego, CA.

This optimistic distance, along with the number applicable installations described in Section 5.1 significantly reduces the applicability of the technology. The only applicable areas are those with dense military installation spacing, like some areas along the US coasts. This spacing also heightens the risks of concurrent outages, lack of locomotive and fuel availability, and route blockages. This distance also assumes flawless coordination between installations, electricians, multiple sets of rail operators, government and civilian businesses, an unused and waiting locomotive with all the required equipment, and no damage to the railroad tracks, all during a likely disaster. Altogether, while response time may be possible under optimistic scenarios it greatly limits its applicability without considering many likely real-world limitations. Given the high degree of variables between to conditions and installation specifics this technology only partially meets this requirement.

8.4 Reduced Cost Compared to Traditional Backup Power Scenario

To better assess the acceptability of this technology as a wide-spread backup power strategy, an economic analysis was performed. Section 6 compared the costs of the rail-to-grid scenario to a traditional backup power scenario of installing a traditional 2MW diesel generator on the installation. For both the rail-to-grid and the 2MW generator financial models, the costs were split into four major categories: Initial Coordination Costs, Initial Capital Costs, Reoccurring Training and Maintenance Costs, and Scenario Costs. The source for this cost data was mainly Gordian's RSMeans (Year 2021), which is North America's leading construction estimating database for decades. Where RSMeans did not readily have data, the team was looking for, industry surveys were performed and other authoritative sources were utilized like the Institute of Electrical and Electronics Engineers (IEEE) and the Energy Information Administration (EIA). This data was then then input into the National Institute of Standards and Technology's (NIST) Building Life Cycle Cost (BLCC) software and run for 10- and 30-year periods. It was assumed no equipment replacement within 30 years, one outage per year, and a 3% discount rate.

To ascertain a better estimate on real-world applicability, the team chose three potential locations from the earlier list of applicable installations. The sites were chosen primarily to represent different regions within the United States and their unique set of cost factors. As a result, the team chose Beale AFB in California for a west coast example, Fort Lee in Virginia for an east coast example, and Camp Shelby in Mississippi for a gulf location. Beale AFB has the highest cost of living index, followed by Ft. Lee, with Camp Shelby having the lowest cost of living. For each of these three locations, local material, labor, and equipment cost factors were acquired from RSMeans 2021 Location Factor indices, local sales taxes were researched, and site factors were calculated via Google Earth. Since there was a large tradeoff between including the high cost of black start drills in exchange for the desired higher reliability of the rail-to-grid scenario, the team included a rail-to-grid scenario both with and without the cost of the black start drills for comparison.

In its essence, this cost comparison is a tradeoff between capital construction costs and labor costs. The rail-to-grid scenario should typically require less initial capital investments in exchange for a higher reoccurring labor costs every year in training, drills, and operation. Consequently, a location performed better if their location cost factors were relatively low for labor like Camp Shelby, MS in contrast to Beale AFB in California. In addition to the higher cost factor index, Beale AFB had a significantly higher cost due to significantly longer distance to connect electrical lines from near the tracks to the substation (~14,200 feet at Beale AFB compared to ~8,900 feet at Ft. Lee and Camp Shelby) and the significantly higher cost of trenching on the West Coast. Based on the results, the only instance of the rail-to-grid scenario being significantly cheaper than the traditional backup power scenario (>30%) is at the location with the cheapest cost factor and without the cost of black start drills factored in. This suggests that rail-to-grid may be economically viable but only under the correct circumstances.

8.5 Enhanced Resilience Compared to Traditional Backup Power Scenario

After doing more research on the rail-to-grid strategy, the team felt it important to add an additional section on resilience. Regardless of how optimistic the current set of assumptions are that are required to make the project potentially feasible, some of the underlying assumptions were found to be lackluster as well.

Primarily, it was reasoned that the strategy would be too slow to remedy most small to medium sized outages and unreliable in most cases of large, long-term scenarios. These larger outages could likewise require the use of these locomotive assets for other important duties like transportation of food, supplies, or military people and equipment. In addition, a 2MW generator comes with additional benefits of allowing peak shaving and demand response programs, selectable equipment siting for added efficiencies. Furthermore, the strategy increases complexity which fundamentally undermines resilience in mechanical systems according to Complexity Theory.

While resilience is notoriously difficult to quantify, and the team doesn't attempt to do so here, it's safe to say that the rail-to-grid scenario generally does not tend to increase resilience over the traditional 2MW generator strategy unless that generator has already failed. Even then there are so many complexities and other variables that it makes it risky to fall back on in a disaster scenario.

9.0 IMPLEMENTATION ISSUES

The rail-to-grid backup power solution did not pass the performance assessment. While the technology is technically feasible, under current real-world conditions it performs worse from operational, applicability, most economic, and resilience standpoints as compared to the traditional backup power benchmark. In addition to these, it also relies on the following list of significant assumptions:

- On-call personnel will be available 24/7 in the event of an emergency
- Locomotive will be available within ~126.5 miles
- Fuel cars will be available at or near that location
- No other outages occurred within one fiscal year
- Commercial crews will be available during a time of emergency
- Commercial crews will be prompt during a time of emergency
- Rail lines are operational before the emergency scenario
- Rail lines are not damaged during/after the emergency scenario
- Radio communications between government and commercial operators can be established and operate during grid outage
- No concurrent outages from the locomotive sending location
- Contracts can be made with all national and unique local parties across 3 different business models
- New contracts won't increase nominal rates
- Routine black start drills are not required
- A microgrid already exists

Nearly any one of these substantial underlying assumptions could metaphorically derail this technology. As a result, the team would not recommend this technology for a common backup power strategy.

To be fair, it could be useful for niche scenarios or in the instance that existing backup power solutions fail during an emergency like the case study from Montreal, Canada. The most reliable application for this technology would be if a locomotive is reliably stationed at an installation and is already onsite with fuel during an outage. However, this largely defeats this study's underlying value proposition of "dispatchable" or "mobile" backup power.

Overall, the last couple years have demonstrated the importance of investing in reliable infrastructure without complex supply chains and interdependencies when it matters most. Consequently, the following motto holds true: "Let us be efficient where we can, and effective where we must." And mission critical backup power is a must.

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Appendix A: Points of Contact

POINT OF CONTACT	ORGANIZATION (Name, Address)	Phone/Fax/ E-mail	Role in Project
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Shane Hirschi	USACE ERDC-CERL 2902 Newmark Dr, Champaign, IL 61822	shane.d.hirschi@usace.army.mil	Co-investigator
Chever H. Kellogg	Army Materiel Command 4400 Martin Road, Redstone Arsenal, Huntsville, AL 35898-5000	(256) 450-7510 DSN: 320-7510; chever.h.kellogg.civ@army.mil	Consultant, Assisted with Survey
Scott W. Van Zile	Defense Finance Accounting Service (Texas)	903-334-1676 DSN 829-1676; Scott.w.vanzile.naf@mail.mil	Consultant, Assisted with Survey

Appendix B: DEPARTMENT OF DEFENSE INSTALLATIONS AND ACTIVITIES REQUIRING RAIL SERVICE (SDDCTEA, 2018)

ACTIVITY	RAILHEAD
ALABAMA	
Anniston Army Depot (AD)	Bynum
Redstone Arsenal	Huntsville
ALASKA	
Eielson Air Force Base (AFB)	Eielson AFB
Joint Base Elmendorf-Richardson (JBER)	JBER
Fort Wainwright	Fort Wainwright
Port of Anchorage	Anchorage
ARIZONA	
Camp Navajo	Bellemont
MCAS Yuma (OP)	Yuma
Yuma Proving Grounds	Blaisdell
ARKANSAS	
Fort Chaffee	Fort Chaffee
Pine Bluff Arsenal	Baldwin
CALIFORNIA	
Beale AFB	Erle
Camp Roberts	McKay
Edwards AFB	Edwards
Fort Irwin (OP)	Yermo
Marine Corp Air Ground Combat Center, 29 Palms (OP)	Nebo, Yermo
Marine Corp Logistics Base (MCLB), Barstow	Nebo, Yermo

Marine Corps Base (MCB), Camp Pendleton	Oceanside
Military Ocean Terminal Concord (MOTCO)	Port Chicago
Naval Air Warfare Center Weapons Division (NAWCWD), China Lake (OP)	Spangler
Port Hueneme	Port Hueneme
Port of Long Beach	Long Beach
CALIFORNIA (Continued)	
Port of Oakland	Oakland
Port of San Diego	San Diego
Sierra AD	Herlong
Vandenburg AFB	Tangair
COLORADO	
Fort Carson	Kelker
Piñon Canyon Maneuver Site (PCMS)	Simpson
CONNECTICUTT	
Camp Hartell	Windsor Locks
Naval Submarine Base (NSB), New London	New London
Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP) Groton	Groton
DELAWARE	
None	
FLORIDA	
USMC Blount Island Command	Blount Island
Naval Ordnance Test Unit (NOTU), Cape Canaveral	Jay Jay
Port of Jacksonville	Blount Island
GEORGIA	

Fort Benning	Ochillee, Sand Hill
Fort Stewart	Walthourville
Hunter Army Airfield (AAF)	Savannah
MCLB, Albany	Dosaga
Naval Submarine Base (NSB) Kings Bay	Kings Bay
Port of Savannah	Savannah
HAWAII	
None	
IDAHO	
Naval Nuclear Laboratory Scoville	Scoville
Orchard Combat Training Center	Orchard
ILLINOIS	
Rock Island Arsenal	Rock Island
INDIANA	
Camp Atterbury	Edinburg
Crane Army Ammunition Activity (AAA)	Crane
Naval Nuclear Propulsion Program (NNPP) Mount Vernon	Mount Vernon
IOWA	
Iowa Army Ammunition Plan (AAP)	Middletown
KANSAS	
Fort Riley	Fort Riley
KENTUCKY	
Blue Grass AD	Fort Estill
Fort Campbell	Casky
Fort Knox	Fort Knox
LOUISIANA	

Fort Polk	Daube Junction
MAINE	
Portsmouth Naval Shipyard	Kittery
MASSACHUSETTS	
Camp Edwards	N. Falmouth
MARYLAND	
Aberdeen Proving Grounds	Aberdeen
Port of Baltimore	Baltimore
United States Property and Fiscal Office (USPFO) Maryland USPFO MD	Havre De Grace
MICHIGAN	
Camp Grayling	Grayling
USPFO Michigan (OP)	Lansing
MINNESOTA	
Camp Ripley	Camp Ripley
MISSISSIPPI	
Camp Shelby	Camp Shelby
Port of Gulfport	Gulfport
MISSOURI	
Fort Leonard Wood	Bundy Junction
USPFO MO	Jefferson City
USPFO – Southeast (SE) Missouri Army National Guard (MOANG) (OP)	Scott City
MONTANA	
Fort Harrison	Helena
Malmstrom AFB	Falls Yard

NEBRASKA	
None	
NEVADA	
Hawthorne AD	Churchill/Thorne
NEW HAMPSHIRE	
Portsmouth Naval Shipyard	Kittery, ME
NEW JERSEY	
Naval Weapons Station (NWS), Earle	Earle
Joint Base McGuire-Dix-Lakehurst (OP)	Morrisville, PA
Port of New York/New Jersey	Elizabethport, NJ
NEW MEXICO	
None	
NEW YORK	
Fort Drum	Calcium
NNPP Kesselring Site (OP)	Ballston Spa
NORTH CAROLINA	
DESC, Millers Siding (Seymour-Johnson AFB)	Goldsboro
Defense Fuel Supply Point (DFSP) Selma	Selma
Fort Bragg	Fort Junction
Marine Corps Air Station (MCAS), Cherry Point	Havelock
MCB Camp Lejeune	Havelock
Military Ocean Terminal Sunny Point (MOTSU)	Leland
Port of Morehead City	Morehead City
Port of Wilmington	Wilmington
NORTH DAKOTA	
None	

OHIO	
Camp Perry Joint Training Center	Port Clinton
Camp Ravenna Joint Military Training Center	Atlas
Joint Systems Manufacturing Center	Lima
NNPP Barberton	Barberton
OKLAHOMA	
Fort Sill	Fort Sill
McAlester AAP	Savanna
OREGON	
None	
PENNSYLVANIA	
DCMA Precision Custom Components	York
Fort Indiantown Gap (OP)	Harrisburg
Letterkenny AD	Culbertson
NAVSUP Weapon Systems Support (WSS), Mechanicsburg	Mechanicsburg
Port of Philadelphia	Philadelphia
Scranton AAP	Scranton
RHODE ISLAND	
None	
SOUTH CAROLINA	
DFSP, Charleston	Charbulk
Fort Jackson (OP)	Columbia
Joint Base Charleston	Inness
Port of Charleston	Charbulk
Shaw AFB	Cane Savannah
SOUTH DAKOTA	

None	
TENNESSEE	
Holston AAP	Holston
Milan AAP	Milan
TEXAS	
Fort Bliss	El Paso
Fort Hood	Killeen
Port of Beaumont	Beaumont
Port of Corpus Christi	Corpus Christi
Port of Port Arthur	Port Arthur
Red River AD	Defense
UTAH	
ATK Thiokol (Magna)	Bacchus
Hill AFB	Hill AFB
Tooele AD	Warner
VERMONT	
None	
VIRGINIA	
DCMA Lynchburg	Mount Athos
Fort Lee	Petersburg
Fort Pickett	Blackstone
Joint Base Langley-Eustis	Lee Hall
Newport News Marine Terminal	Newport News
Norfolk International Terminal	Norfolk
Norfolk Naval Shipyard	Portsmouth
Portsmouth Marine Terminal	Portsmouth

Radford AAP	Cowan, Pepper
SUPSHIP Newport News	Newport News
WASHINGTON	
Indian Island (OP)	Bangor
Joint Base Lewis-McChord	Mobase, Tacoma
Naval Base Kitsap, Bangor	Bangor
Naval Base Kitsap, Bremerton	Bremerton
Port of Tacoma	Tacoma
Puget Sound Naval Shipyard	Bremerton
Yakima Training Center	Pomona
WEST VIRGINIA	
None	
WISCONSIN	
Fort McCoy	Fort McCoy
WYOMING	
None	

DEPARTMENT OF DEFENSE INSTALLATIONS AND ACTIVITIES REQUIRING RAIL BY SERVICE

ARMY	STATE
Fort Wainwright	AK
Fort Chaffee	AR
Camp Roberts	CA
Piñon Canyon Maneuver Site (PCMS)	CO
Camp Hartell	CT
Port of Jacksonville	FL
Fort Benning	GA

Crane Army Ammunition Activity	IN
USPFO MD	MD
Camp Edwards	MA
Camp Grayling	MI
Camp Ripley	MN
Camp Shelby	MS
USPFO - SE (MOANG) (OP)	MO
Hawthorne AD	NV
Fort Bragg	NC
MOTSU	NC
Port of Morehead City	NC
Fort Sill	OK
Letterkenny AD	PA
Fort Lee	VA
Indian Island	WA
Joint Base Lewis-McChord	WA
TOTAL 23	

AIR FORCE	STATE
Eielson AFB	AK
Vandenburg AFB	CA
Malmstrom AFB	MT
Shaw AFB	SC
Hill AFB	UT
TOTAL 5	

NAVY	STATE

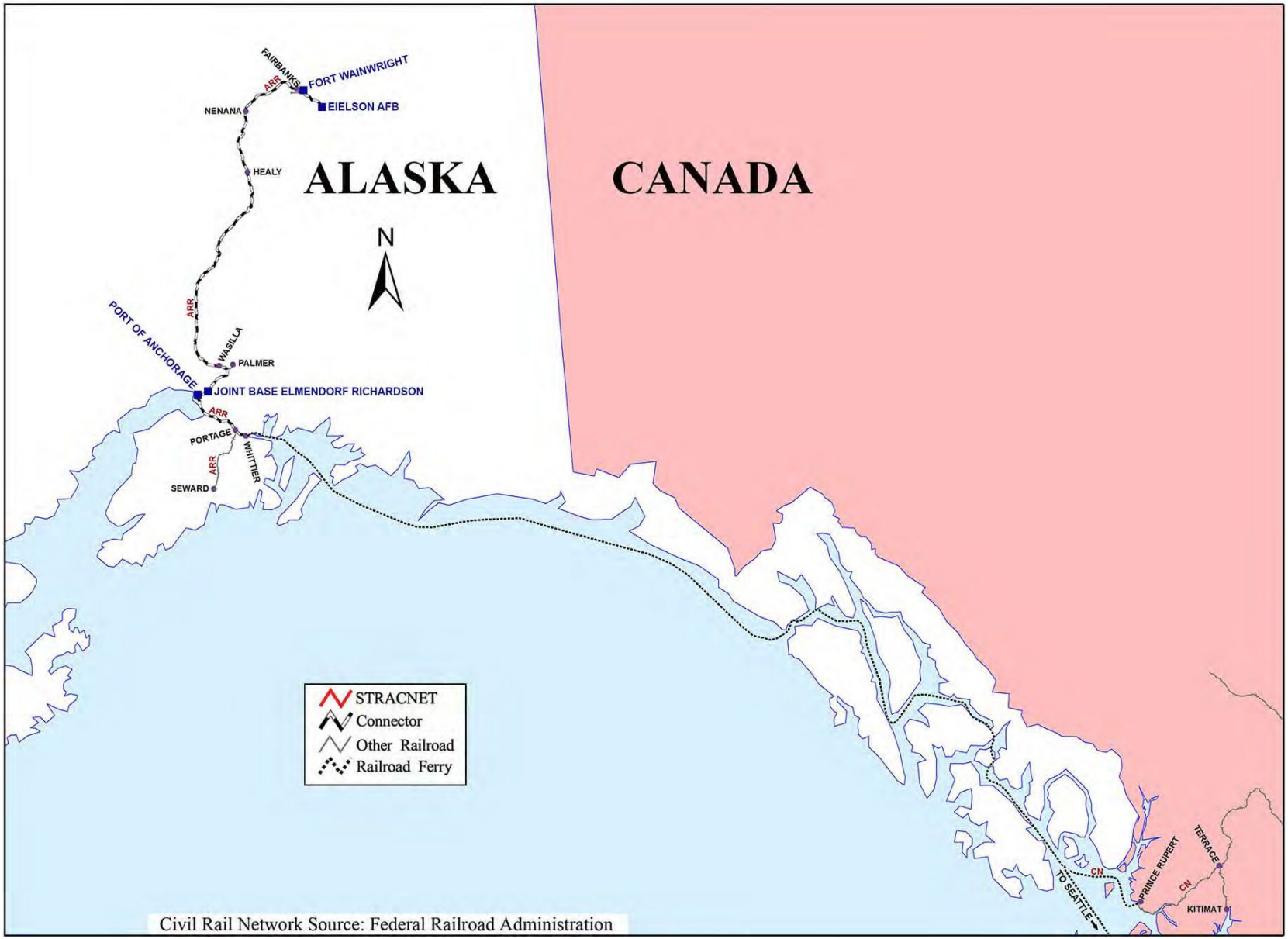
NAWCWD, China Lake (OP)	CA
Port Hueneme	CA
NSB New London	CT
SUPSHIP Groton	CT
NSB Kings Bay	GA
Naval Nuclear Laboratory Scoville	ID
NNPP Mount Vernon	IN
Naval Shipyard, Portsmouth	NH
NWS Earle	NJ
NNPP Kesselring Site	NY
DCMA Precision Custom Components	PA
NAVSUP WSS Mechanicsburg	PA
Naval Base Kitsap, Bangor	WA
Naval Base Kitsap, Bremerton	WA
TOTAL 14	

MARINE CORPS	STATE
USMC Blount Island Command	FL
MCLB Albany	GA
MCAS Cherry Point	NC
MCB Camp Lejeune	NC
TOTAL 4	

DEFENSE CONTRACT MANAGEMENT AGENCY (DCMA)	STATE
ATK Thiokol (Magna)	UT
TOTAL 1	

DEFENSE LOGISTICS AGENCY (DLA)	STATE
No installations on low-density rail lines	

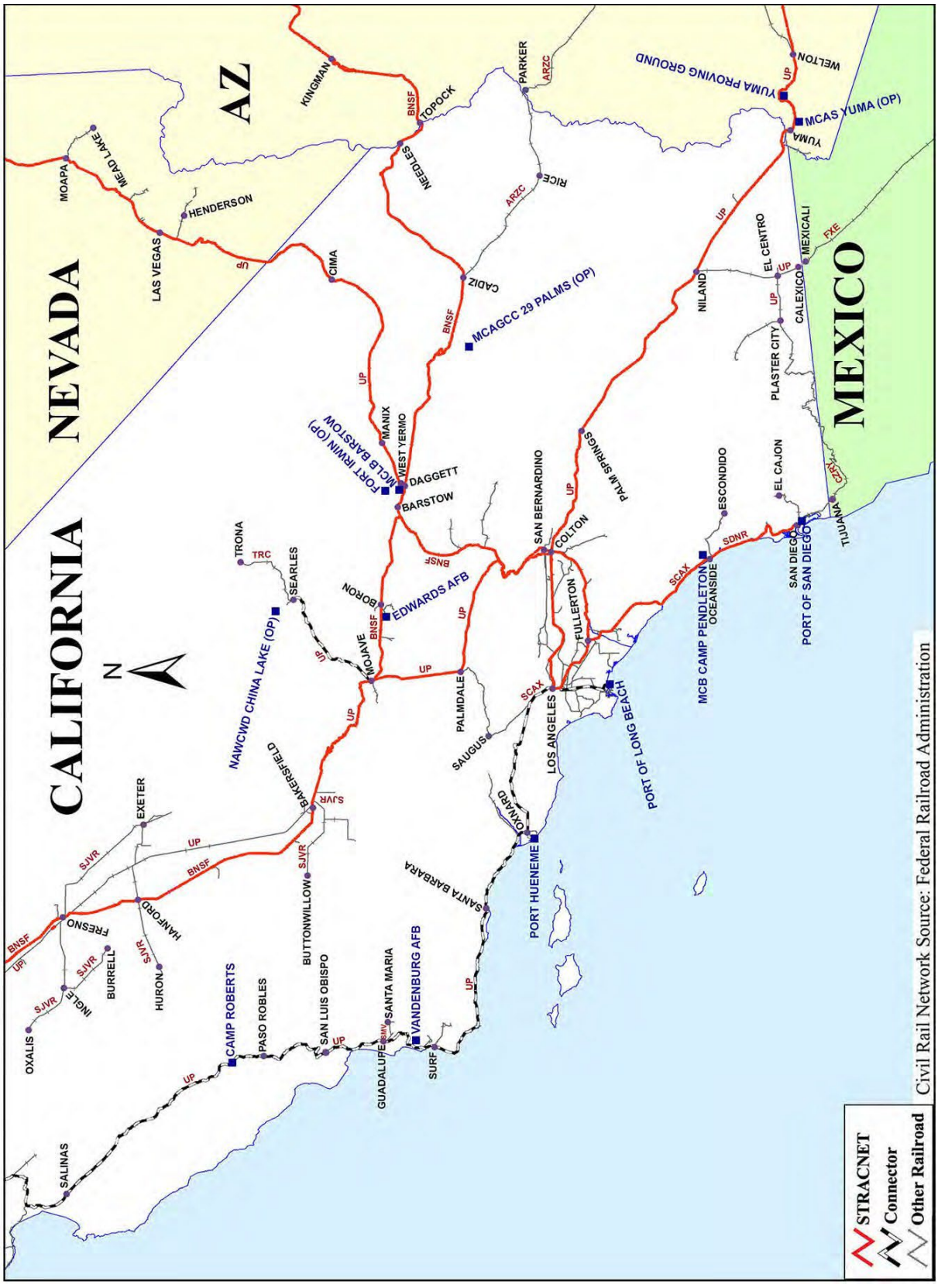
Appendix C: STRACNET State Maps (SDDCTEA, 2018)


ALASKA
CANADA
N
FAIRBANKS
ARR
FORT WAINWRIGHT
EIELSON AFB
NENANA
HEALY
ARR
WASILLA
PALMER
PORT OF ANCHORAGE
JOINT BASE ELMENDORF RICHARDSON
ARR
PORTAGE
WHITTIER
ARR
SEWARD
STRACNET
Connector
Other Railroad
Railroad Ferry
TO SEATTLE
CN
PRINCE RUPERT
CN
TERRACE
KITIMAT
Civil Rail Network Source: Federal Railroad Administration

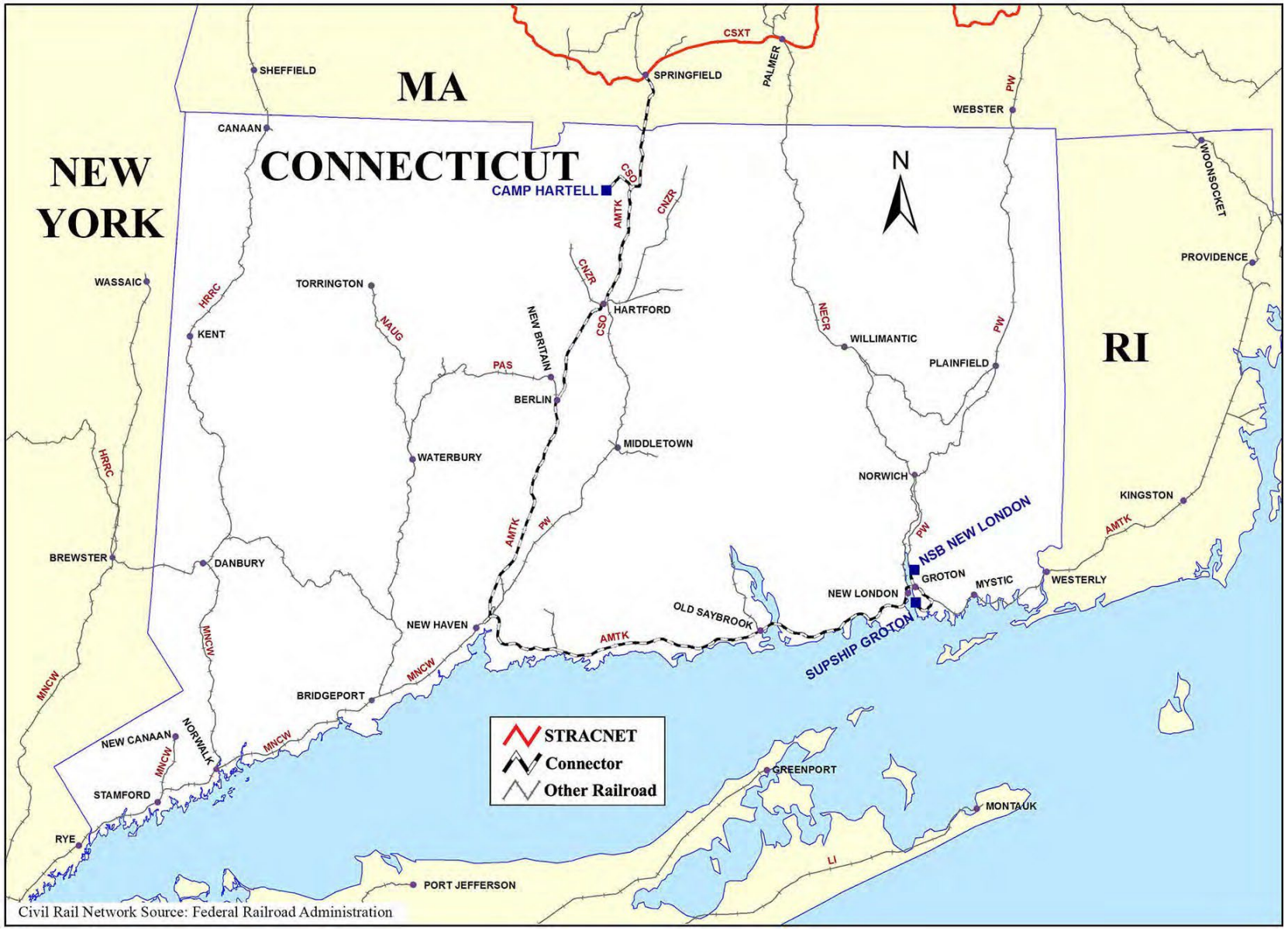
NEVADA
UTAH
CO
ARIZONA
N
CA
MEXICO
NM
LUND
CEDAR CITY
IRON MOUNTAIN
CALIENTE
MOAPA
MEAD LAKE
LAS VEGAS
HENDERSON
CIMA
GRAND CANYON
NELSON
SELIGMAN
GCRX
WILLIAMS JCT.
CAMP NAVAJO
FLAGSTAFF
GALLUP
KINGMAN
ASH FORK
WINSLOW
HOLBROOK
NAVAJO
NEEDLES
CADIZ
TOPOCK
DRAKE
AZCR
CLARKDALE
HILLSIDE
SNOWFLAKE
SPRINGERVILLE
RICE
PARKER
MATTHIE
ARLINGTON
PHOENIX
WILAND
EL CENTRO
CALEXICO
YUMA PROVING GROUND
MIAMI
CLIFTON
MAGMA
CBRY
GILA
MARICOPA
PICACHO
SMA
SAN MANUEL
AZER
MEXICALI
YUMA
MCAS YUMA (OP)
WELTON
TUCSON
BENSON
BOWIE
LORDSBURG
SPSR
CURTISS
NOGALES
FXE
BENJAMIN HILL
BNSF
UP
ARZC
APA
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

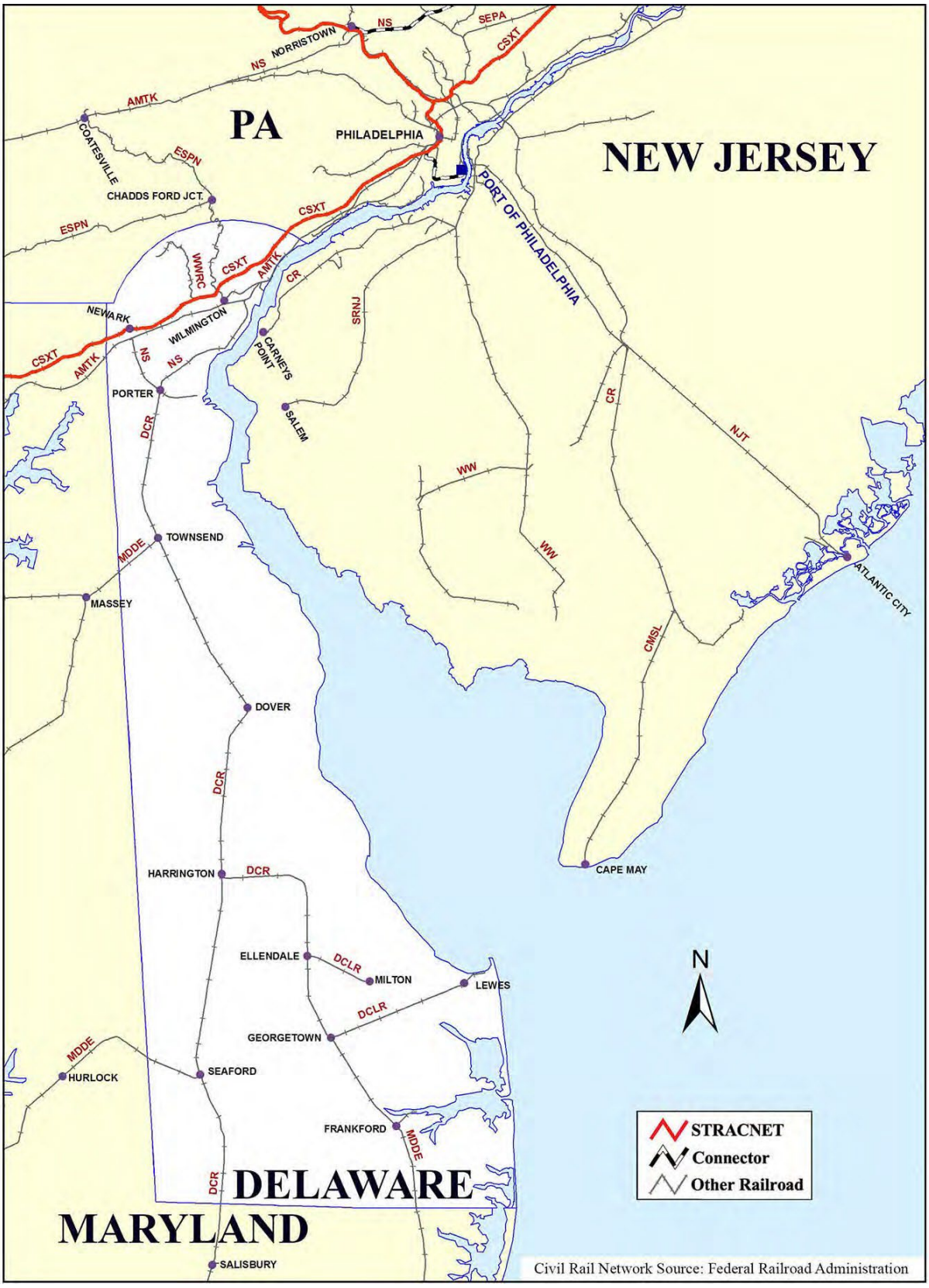
MISSOURI
ARKANSAS
OKLAHOMA
TEXAS
LA
MS
TN
KY
N
NEOSHO
WILLOW SPRINGS
WEST PLAINS
POPLAR BLUFF
DEXTER
HICKMAN
MALDEN
LILBOURN
BRANSON
BERGMAN
ROGERS
BENTONVILLE
FAYETTEVILLE
TULSA
CLAREMORE
VINITA
AFTON
WAGONER
MUSKOGEE
SALLISAW
VAN BUREN
FORT SMITH
FSR
FORT CHAFFEE
HOWE
POTEAU
MCALESTER
MCALESTER AAP
HEAVENER
WALDRON
RUSSELLVILLE
DANVILLE
LITTLE ROCK
PINE BLUFF ARSENAL
BATESVILLE
NEWPORT
BALD KNOB
HOXIE
JONESBORO
NETTLETON
BLYTHEVILLE
DYERSBURG
TURRELL
MEMPHIS
FAIR OAKS
WYNNE
BRINKLEY
FORREST CITY
LAKE COMORANT
HOLLY SPRINGS
GRAND JCT.
HELENA
MARKS
CLARKSDALE
GRENADA
GREENWOOD
WINONA
GREENVILLE
DURANT
YAZOO CITY
LAKE PROVIDENCE
LAKE VILLAGE
MONTROSE
MCGEHEE
WARREN
CROSSETT
BASTROP
EL DORADO
CAMDEN
MCNEIL
LEWISVILLE
TEXARKANA
RED RIVER ARMY DEPOT
SPRINGHILL
MT. PLEASANT
PITTSBURG
JEFFERSON
PARIS
ANTLERS
HUGO
VALLIANT
IDABEL
DEQUEEN
PERKINS
ARKADELPHIA
MALVERN
GURDON
HOPE
ASHDOWN
FORDYCE
PINE BLUFF
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

OREGON
NEVADA
CALIFORNIA
N
MEDFORD
ASHLAND
CORP
KLAMATH FALLS
LAKEVIEW
YREKA
MONTAGUE
CORP
BLACK BUTTE
UP
BNSF
BIEBER
GOOS
ALTURAS
REDDING
TEHAMA
WYO
KEDDIE
SIERRA ARMY DEPOT
HERLONG
FLANIGAN
GERLACH
RENO JCT.
RENO
HAZEN
FALLON
WABUSKA
USG
HAWTHORNE ARMY DEPOT
MARYSVILLE
BEALE AFB
CFNR
ROSEVILLE
SERA
DAVIS
SACRAMENTO
KRUG
NVRR
SANTA ROSA
NWP
MOTCO
SAN RAFAEL
PORT OF OAKLAND
SAN FRANCISCO
TRACY
STOCKTON
RIVERBANK
EMPIRE
MODESTO
SAN JOSE
MERCED
LOS BANOS
OXALIS
FRESNO
INGLE
BURRELL
HANFORD
HURON
EXETER
SJVR
SALINAS
CAMP ROBERTS
PASO ROBLES
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

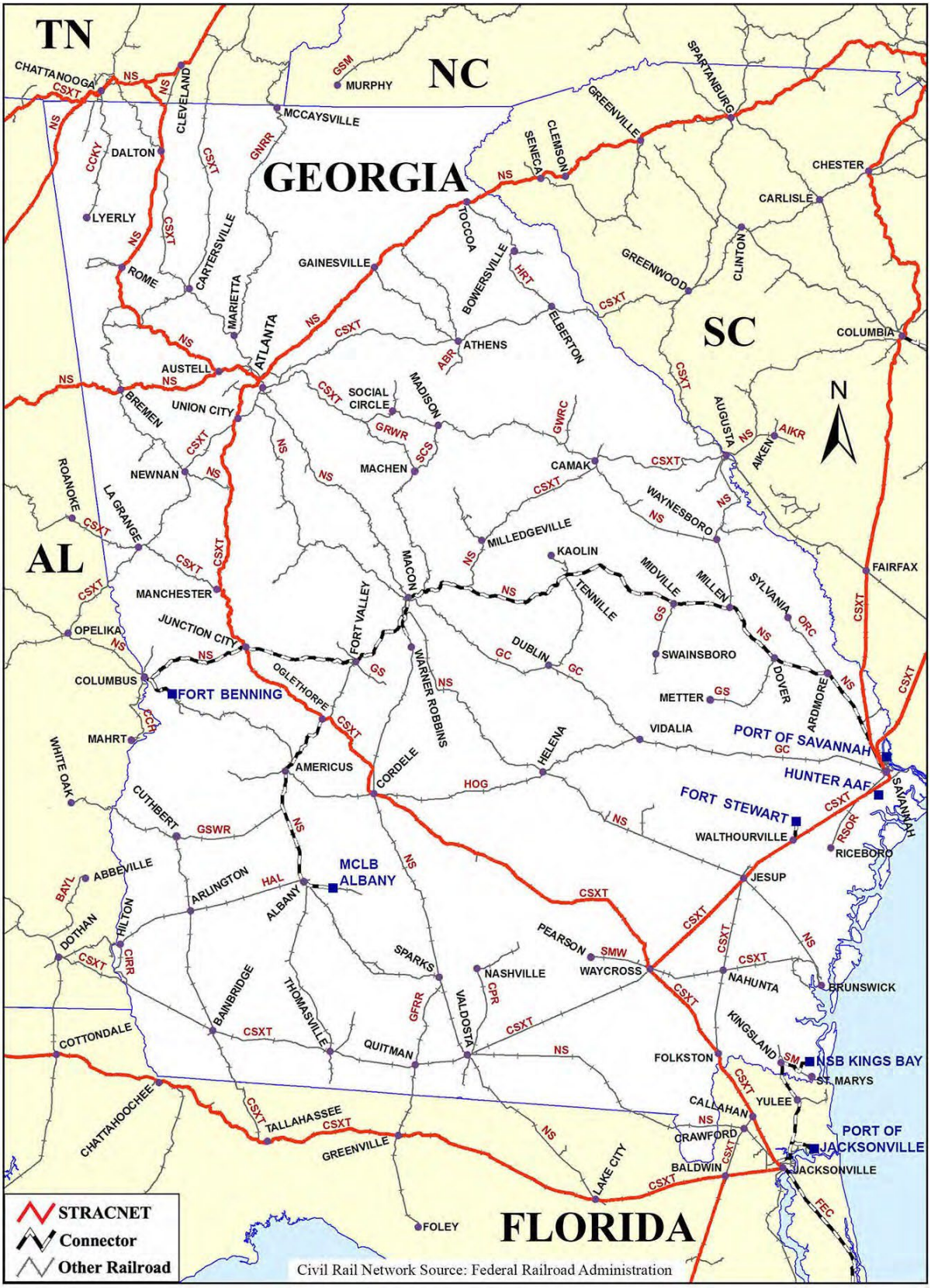

CALIFORNIA
NEVADA
AZ
MEXICO
N
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
KINGMAN
TOPOCK
PARKER
YUMA PROVING GROUND
WELTON
MCAS YUMA (OP)
YUMA
MOAPA
MEAD LAKE
HENDERSON
LAS VEGAS
NEEDLES
RICE
CIMA
CADIZ
MCAGCC 29 PALMS (OP)
NILAND
EL CENTRO
MEXICALI
CALEXICO
PLASTER CITY
FORT IRWIN (OP)
MCLB BARSTOW
MANIX
WEST YERMO
DAGGETT
BARSTOW
PALM SPRINGS
SAN BERNARDINO
COLTON
ESCONDIDO
EL CAJON
SAN DIEGO
PORT OF SAN DIEGO
TIJUANA
TRONA
TRC
SEARLES
NAWCWD CHINA LAKE (OP)
BORON
EDWARDS AFB
MOJAVE
FULLERTON
MCB CAMP PENDLETON
OCEANSIDE
PORT OF LONG BEACH
LOS ANGELES
PALMDALE
SAUGUS
BAKERSFIELD
EXETER
FRESNO
HANFORD
BURRELL
INGLE
HURON
OXALIS
SALINAS
CAMP ROBERTS
PASO ROBLES
BUTTONWILLOW
SAN LUIS OBISPO
GUADALUPE
SANTA MARIA
VANDENBURG AFB
SURF
SANTA BARBARA
OXNARD
PORT HUENEME
UP
BNSF
SJVR
ARZC
SCAX
SDNR
FXE
CPKC

Civil Rail Network Source: Federal Railroad Administration

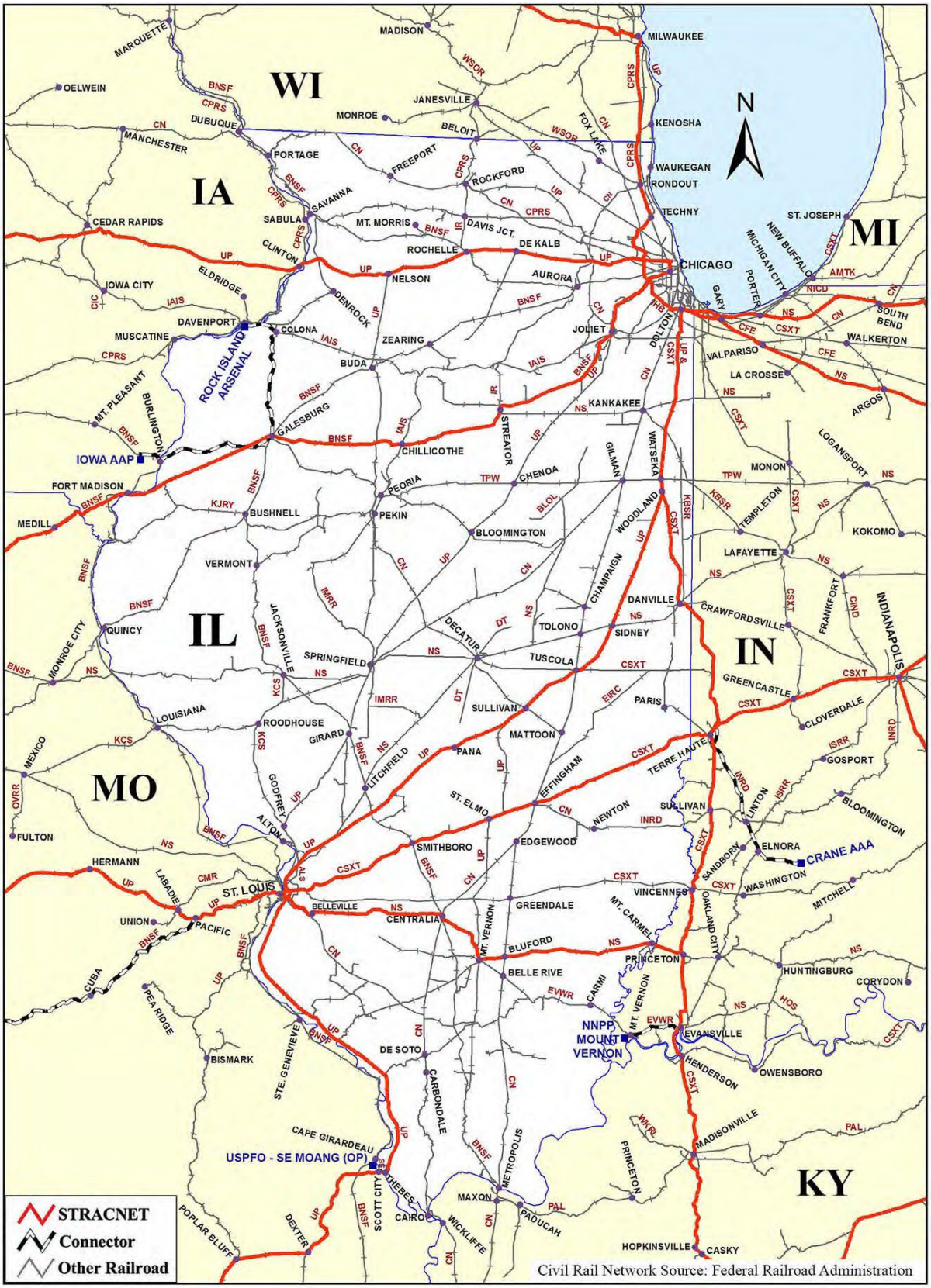

MA
CONNECTICUT
NEW YORK
RI
CAMP HARTELL
SHEFFIELD
CANAAN
SPRINGFIELD
CSXT
PALMER
WEBSTER
PW
WOONSOCKET
PROVIDENCE
N
WASSAIC
TORRINGTON
HARTFORD
CSO
AMTK
CNZR
HRRC
KENT
NAUG
NEW BRITAIN
PAS
BERLIN
NECR
WILLIMANTIC
PLAINFIELD
WATERBURY
MIDDLETOWN
NORWICH
KINGSTON
BREWSTER
DANBURY
NSB NEW LONDON
GROTON
MYSTIC
WESTERLY
NEW LONDON
OLD SAYBROOK
NEW HAVEN
SUPSHIP GROTON
MNCW
BRIDGEPORT
NEW CANAAN
NORWALK
STAMFORD
RYE
GREENPORT
MONTAUK
LI
PORT JEFFERSON
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


PA
NEW JERSEY
DELAWARE
MARYLAND
PHILADELPHIA
NORRISTOWN
COATESVILLE
CHADDS FORD JCT.
NEWARK
WILMINGTON
PORTER
CARNEYS POINT
SALEM
PORT OF PHILADELPHIA
TOWNSEND
MASSEY
DOVER
HARRINGTON
ELLENDALE
MILTON
LEWES
GEORGETOWN
SEAFORD
HURLOCK
FRANKFORD
SALISBURY
ATLANTIC CITY
CAPE MAY
NS
SEPA
CSXT
AMTK
ESPN
WMRC
CR
SRNJ
NJT
WW
CMSL
DCR
DCLR
MDDE
N
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

Civil Rail Network Source: Federal Railroad Administration


TN
NC
GEORGIA
SC
AL
FLORIDA
CHATTANOOGA
MURPHY
MCCAYSVILLE
CLEVELAND
DALTON
LYERLY
ROME
CARTERSVILLE
MARIETTA
ATLANTA
GAINESVILLE
TOCCOA
BOWERSVILLE
ELBERTON
ATHENS
GREENVILLE
SPARTANBURG
CLEMSON
SENECA
CHESTER
CARLISLE
GREENWOOD
CLINTON
COLUMBIA
AUGUSTA
AIKEN
AUSTELL
BREMEN
UNION CITY
SOCIAL CIRCLE
MADISON
MACHEN
CAMAK
NEWNAN
ROANOKE
LA GRANGE
MANCHESTER
OPELIKA
JUNCTION CITY
COLUMBUS
FORT BENNING
MILLEDGEVILLE
KAOLIN
MACON
FORT VALLEY
TENNILLE
MIDVILLE
MILLEN
SYLVANIA
WAYNESBORO
FAIRFAX
SWAINSBORO
DUBLIN
METTER
DOVER
ARDMORE
VIDALIA
PORT OF SAVANNAH
HUNTER AAF
SAVANNAH
FORT STEWART
WALTHOURVILLE
RICEBORO
JESUP
MAHRT
WHITE OAK
CUTHBERT
AMERICUS
CORDELE
WARNER ROBBINS
HELENA
OGLETHORPE
MCLB ALBANY
ABBEVILLE
ARLINGTON
ALBANY
DOTHAN
HILTON
BAINBRIDGE
THOMASVILLE
SPARKS
NASHVILLE
PEARSON
WAYCROSS
NAHUNTA
BRUNSWICK
KINGSLAND
NSB KINGS BAY
ST. MARYS
COTTONDALE
QUITMAN
VALDOSTA
FOLKSTON
CALLAHAN
YULEE
PORT OF JACKSONVILLE
JACKSONVILLE
CRAWFORD
BALDWIN
LAKE CITY
TALLAHASSEE
GREENVILLE
CHATTAHOOCHEE
FOLEY
N
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

CANADA
MONTANA
IDAHO
WA
OR
NV
WY
UTAH
N
CPRS
YAHK
EASTPORT
STIRLING
COUTTS
METALINE FALLS
KETTLE FALLS
KFR
NEWPORT
POVA
SANDPOINT
BONNERS FERRY
UP
BNSF
EUREKA
MMT
LIBBY
STRYKER
COLUMBIA FALLS
KALISPELL
BROWNING
SWEET GRASS
CUT BANK
SHELBY
VALIER
CHOTEAU
POWER
GREAT FALLS
MALMSTROM AFB
FAIRFIELD
SPOKANE
EWG
CHENEY
WR
ST. MARIES
PALOUSE
PULLMAN
MOSCOW
GRNW
LEWISTON
BGCM
KOOSKIA
THOMPSON FALLS
MRL
PARADISE
ST. REGIS
DIXON
MISSOULA
DE SMET
DARBY
GARRISON
HELENA
FORT HARRISON
BUTTE
SILVER BOW
WHITEHALL
LOGAN
BOZEMAN
LIVINGSTON
BARRETTS
DELL
MONIDA
DUBOIS
ASHTON
NEWDALE
EIRR
IDAHO FALLS
BLACKFOOT
ABERDEEN
POCATELLO
MCCAMMON
ALEXANDER
CONDA
PRESTON
CACHE JCT.
MALAD
KEMMERER
BAKER
HUNTINGTON
PAYETTE
INPR
CASCADE
VALE
WILDER
SVRR
BOISE
NAMPA
ORCHARD
ORCHARD COMBAT TRAINING CENTER
MOUNTAIN HOME
SHOSHONE
WENDELL
BUHL
TWIN FALLS
MINIDOKA
RUPERT
NAVAL NUCLEAR LABORATORY SCOVILLE
USG
SCOVILLE
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


WI
IA
IL
MO
IN
MI
KY
N
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
IOWA AAP
ROCK ISLAND ARSENAL
USPFO - SE MOANG (OP)
NNPP MOUNT VERNON
CRANE AAA
CHICAGO
ST. LOUIS
MILWAUKEE
MADISON
MARQUETTE
OELWEIN
DUBUQUE
MANCHESTER
CEDAR RAPIDS
IOWA CITY
DAVENPORT
MUSCATINE
MT. PLEASANT
BURLINGTON
FORT MADISON
MEDILL
QUINCY
MONROE CITY
LOUISIANA
MEXICO
FULTON
HERMANN
UNION
CUBA
PEA RIDGE
BISMARK
CAPE GIRARDEAU
DEXTER
POPLAR BLUFF
SCOTT CITY
THEBES
CAIRO
WICKLIFFE
PADUCAH
MAXON
HOPKINSVILLE
CASKY
MADISONVILLE
OWENSBORO
HENDERSON
EVANSVILLE
HUNTINGBURG
CORYDON
PRINCETON
VINCENNES
TERRE HAUTE
SULLIVAN
ELNORA
BLOOMINGTON
GOSPORT
CLOVERDALE
GREENCASTLE
CRAWFORDSVILLE
INDIANAPOLIS
LAFAYETTE
KOKOMO
LOGANSPORT
ARGOS
WALKERTON
SOUTH BEND
MICHIGAN CITY
NEW BUFFALO
ST. JOSEPH
WAUKEGAN
KENOSHA
RONDOUT
TECHNY
GARY
PORTER
VALPARISO
LA CROSSE
JOLIET
AURORA
DE KALB
ROCHELLE
DAVIS JCT.
MT. MORRIS
SAVANNA
SABULA
CLINTON
ELDRIDGE
NELSON
DENROCK
COLONA
ZEARING
BUDA
GALESBURG
CHILLICOTHE
PEORIA
CHENOA
BUSHNELL
PEKIN
BLOOMINGTON
VERMONT
SPRINGFIELD
DECATUR
TUSCOLA
SIDNEY
TOLONO
CHAMPAIGN
DANVILLE
KANKAKEE
WATSEKA
GILMAN
STREATOR
MONON
TEMPLETON
ROODHOUSE
GIRARD
LITCHFIELD
PANA
MATTOON
EFFINGHAM
ST. ELMO
NEWTON
SULLIVAN
PARIS
EDGEWOOD
SMITHBORO
GREENDALE
BELLEVILLE
CENTRALIA
MT. VERNON
BLUFORD
BELLE RIVE
CARMI
EVWR
DE SOTO
CARBONDALE
METROPOLIS
PRINCETON
OAKLAND CITY
SANDBORN
WASHINGTON
MITCHELL
ALTON
GODFREY
JACKSONVILLE
IMRR
CMR
LABADIE
PACIFIC
STE. GENEVIEVE
OVRR
KCS
BNSF
UP
CSXT
NS
CN
IAIS
CPRS
WSOR
FOX LAKE
FREEPORT
ROCKFORD
BELOIT
JANESVILLE
PORTAGE
CIC
IR
TPW
BLOL
KJRY
DT
EIRC
INRD
ISRR
KBSR
CFE
NICD
AMTK
HB
DOLTON
CIND
FRANKFORT

STRACNET
Connector
Other Railroad
MI
IL
INDIANA
OH
KY
N
CHICAGO
WAUKEGAN
RONDOUT
TECHNY
ST. JOSEPH
KALAMAZOO
BATTLE CREEK
JACKSON
SCHOOLCRAFT
HILLSDALE
MONTPELIER
STEUBENVILLE
DE KALB
AURORA
JOLIET
GARY
PORTER
MICHIGAN CITY
NEW BUFFALO
WHITE PIGEON
ELKHART
GOSHEN
SOUTH BEND
WALKERTON
BUTLER
BRYAN
VALPARISO
PLYMOUTH
MILFORD JCT.
ST. JOE
LA CROSSE
WARSAW
ARGOS
CLAYPOOL
FORT WAYNE
VAN WERT
KANKAKEE
STREATOR
CHENOA
GILMAN
WATSEKA
MONON
LOGANSPORT
WABASH
GLENMORE
BLUFFTON
WOODLAND
TEMPLETON
KOKOMO
MARION
HARTFORD CITY
COLDWATER
LAFAYETTE
TIPTON
RED KEY
MUNCIE
FRANKFORT
ANDERSON
UNION CITY
DANVILLE
CRAWFORDSVILLE
NEW CASTLE
RICHMOND
TUSCOLA
INDIANAPOLIS
CONNERSVILLE
GREENCASTLE
PARIS
CLOVERDALE
SHELBYVILLE
COTTAGE GROVE
HAMILTON
MATTOON
TERRE HAUTE
GOSPORT
EDINBURG
GREENSBURG
BROOKVILLE
EFFINGHAM
ST. ELMO
SULLIVAN
LINTON
BLOOMINGTON
CAMP ATTERBURY
COLUMBUS
SEYMOUR
NORTH VERNON
CINCINNATI
NEWTON
EDGEWOOD
ELNORA
CRANE AAA
MADISON
VINCENNES
MITCHELL
WASHINGTON
GREENDALE
MT. CARMEL
SANDBORN
OAKLAND CITY
BLUFORD
PRINCETON
NEW ALBANY
SHELBYVILLE
FRANKFORT
BELLE RIVE
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BARDSTOWN
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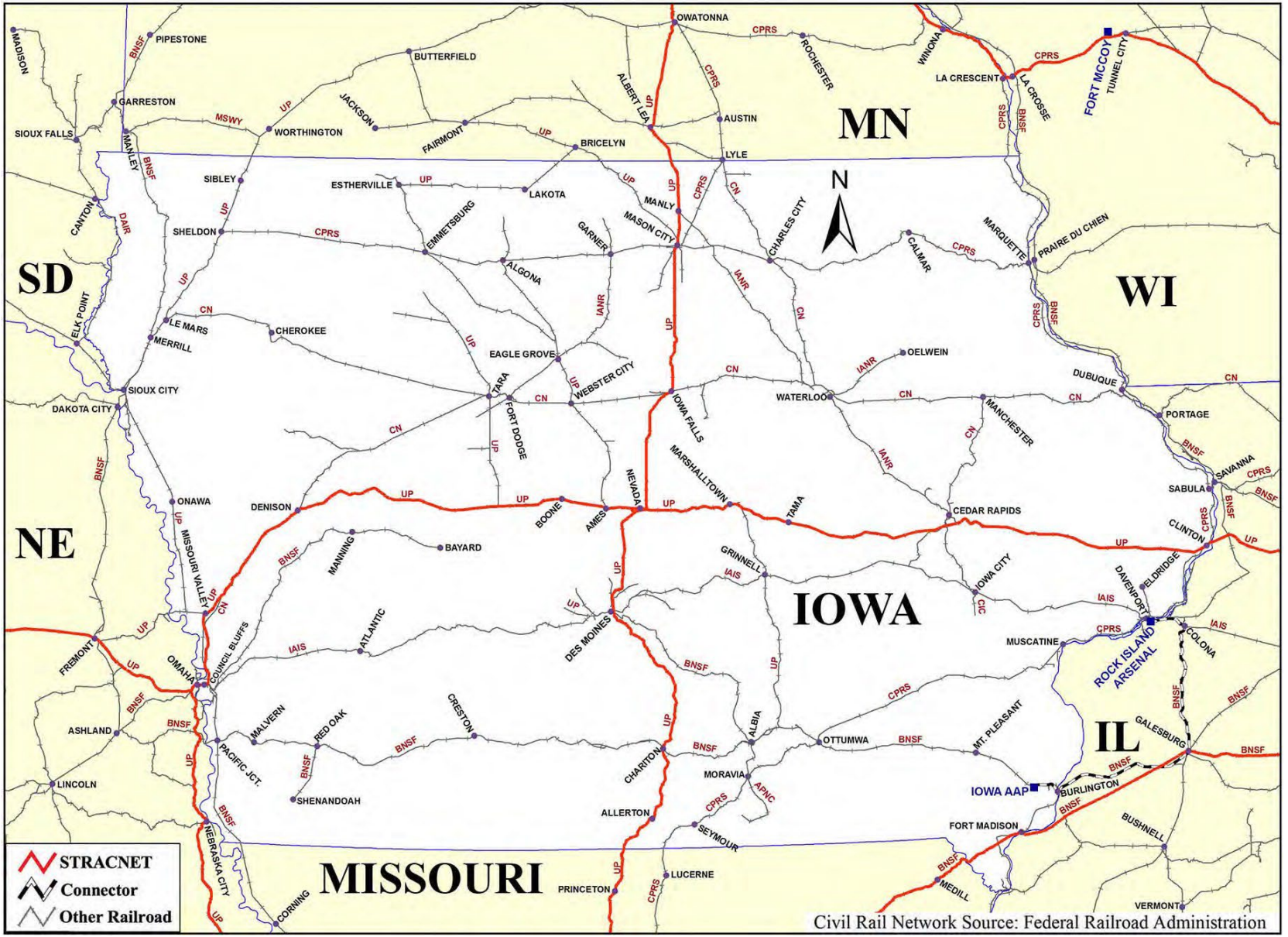
ELIZABETHTOWN
DANVILLE
Civil Rail Network Source: Federal Railroad Administration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Civil Rail Network Source: Federal Railroad Administration
OWATONNA
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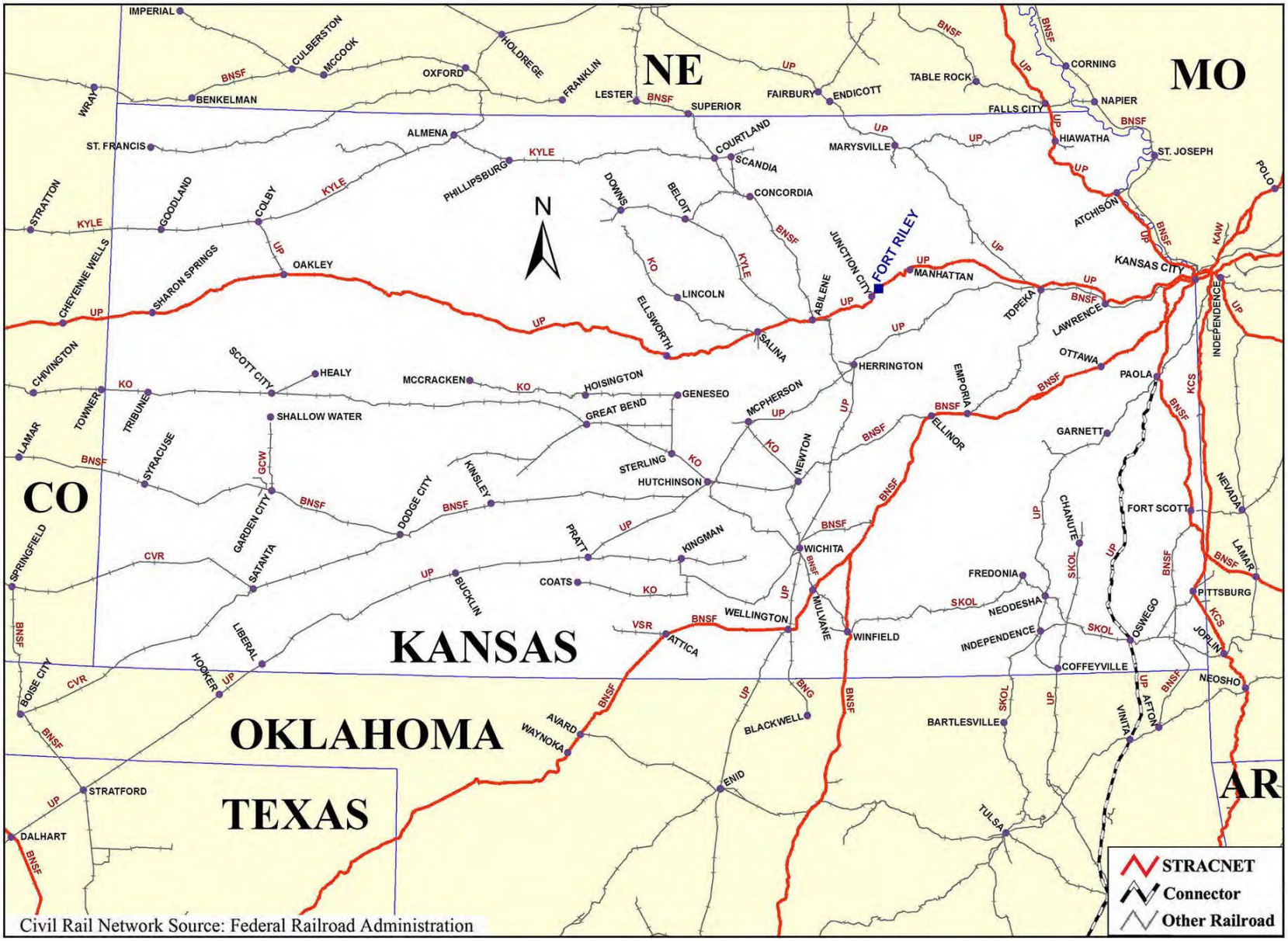
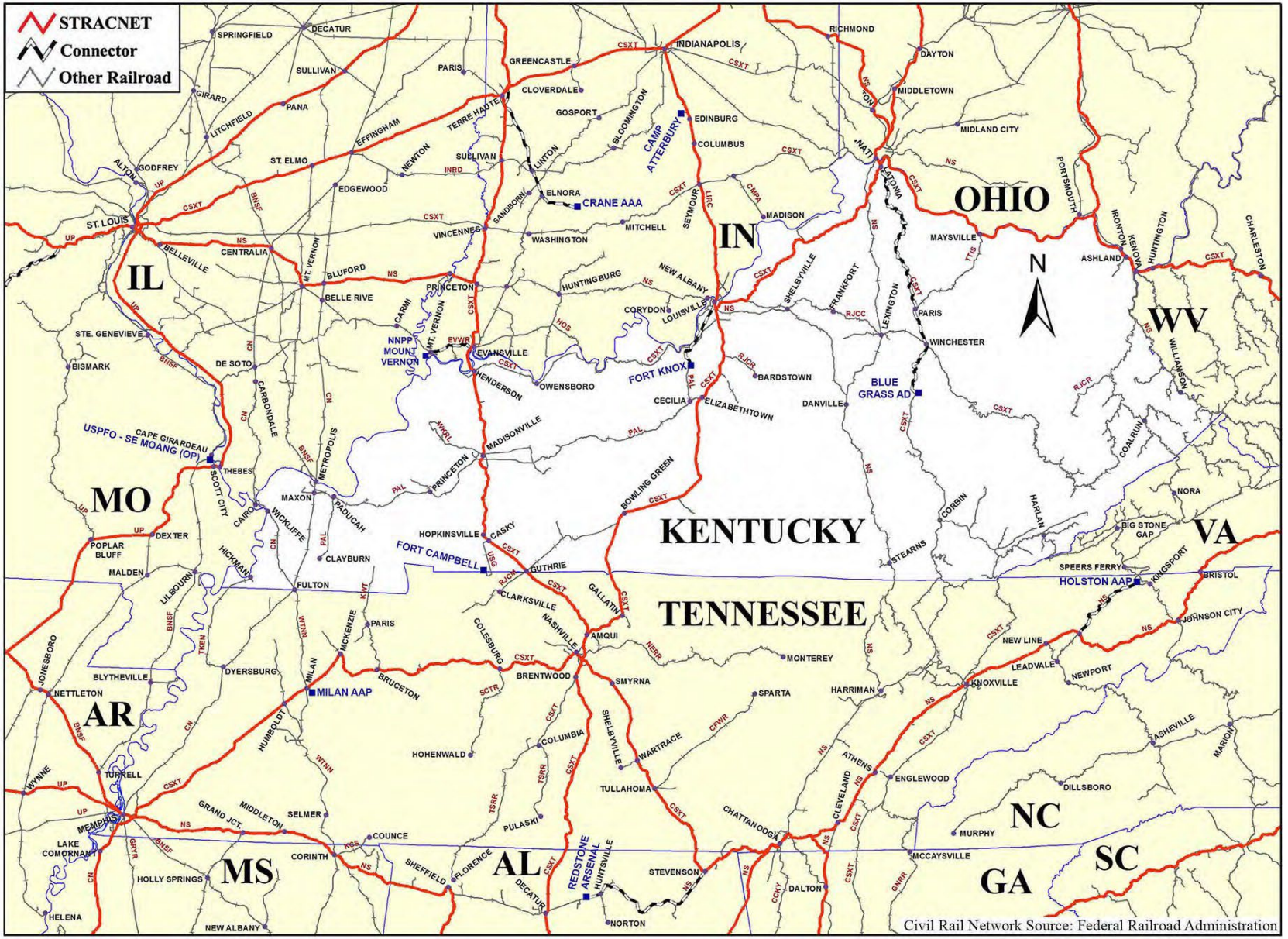


Civil Rail Network Source: Federal Railroad Administration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Civil Rail Network Source: Federal Railroad Administration

STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
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FORT POLK
CAMP SHELBY
PORT OF GULFPORT
PORT OF BEAUMONT
PORT OF PORT ARTHUR
TEXARKANA
SHREVEPORT
MONROE
VICKSBURG
JACKSON
MERIDIAN
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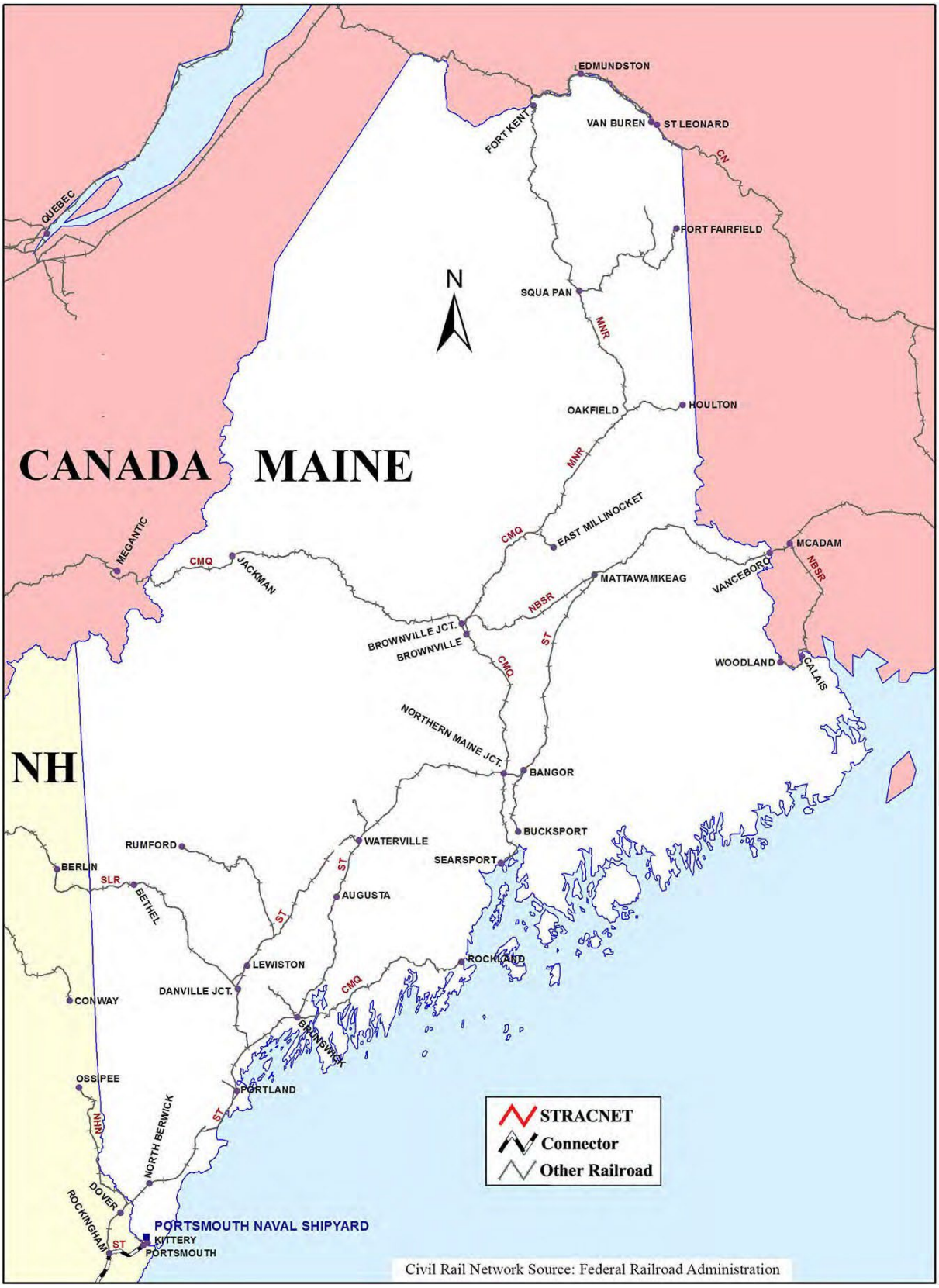
HOUSTON
GALVESTON
BEAUMONT


EDMUNDSTON
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EAST MILLINOCKET
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MATTAWAMKEAG
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NORTHERN MAINE JCT.
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WATERVILLE
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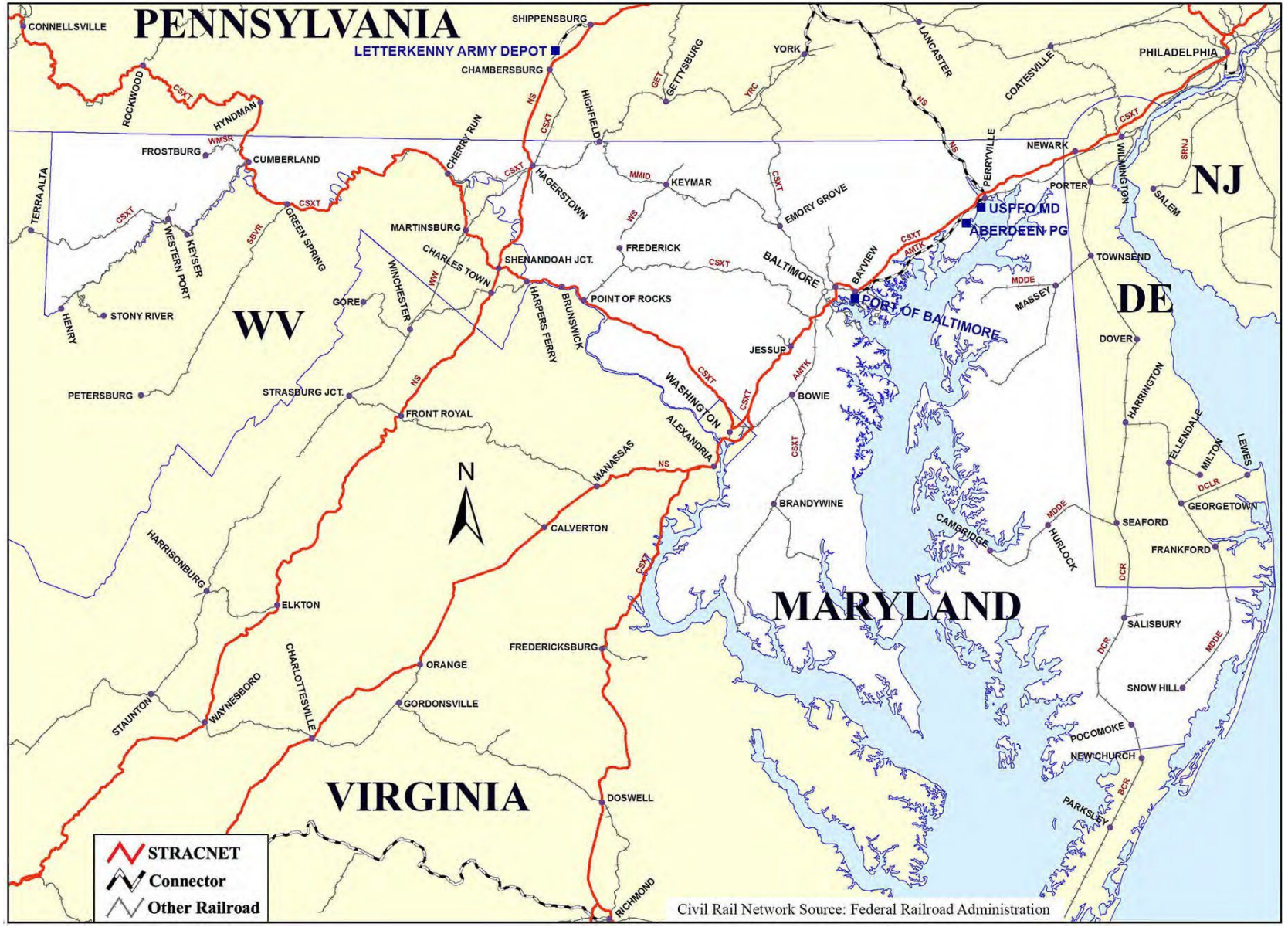
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


PENNSYLVANIA
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PORT OF BALTIMORE
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PHILADELPHIA
COATESVILLE
NEWARK
WILMINGTON
PERRYVILLE
ROCKWOOD
HYNDMAN
FROSTBURG
CUMBERLAND
TERRA ALTA
KEYSER
WESTERN PORT
GREEN SPRING
MARTINSBURG
CHERRY RUN
HAGERSTOWN
HIGHFIELD
GETTYSBURG
KEYMAR
EMORY GROVE
FREDERICK
SHENANDOAH JCT.
CHARLES TOWN
HARPERS FERRY
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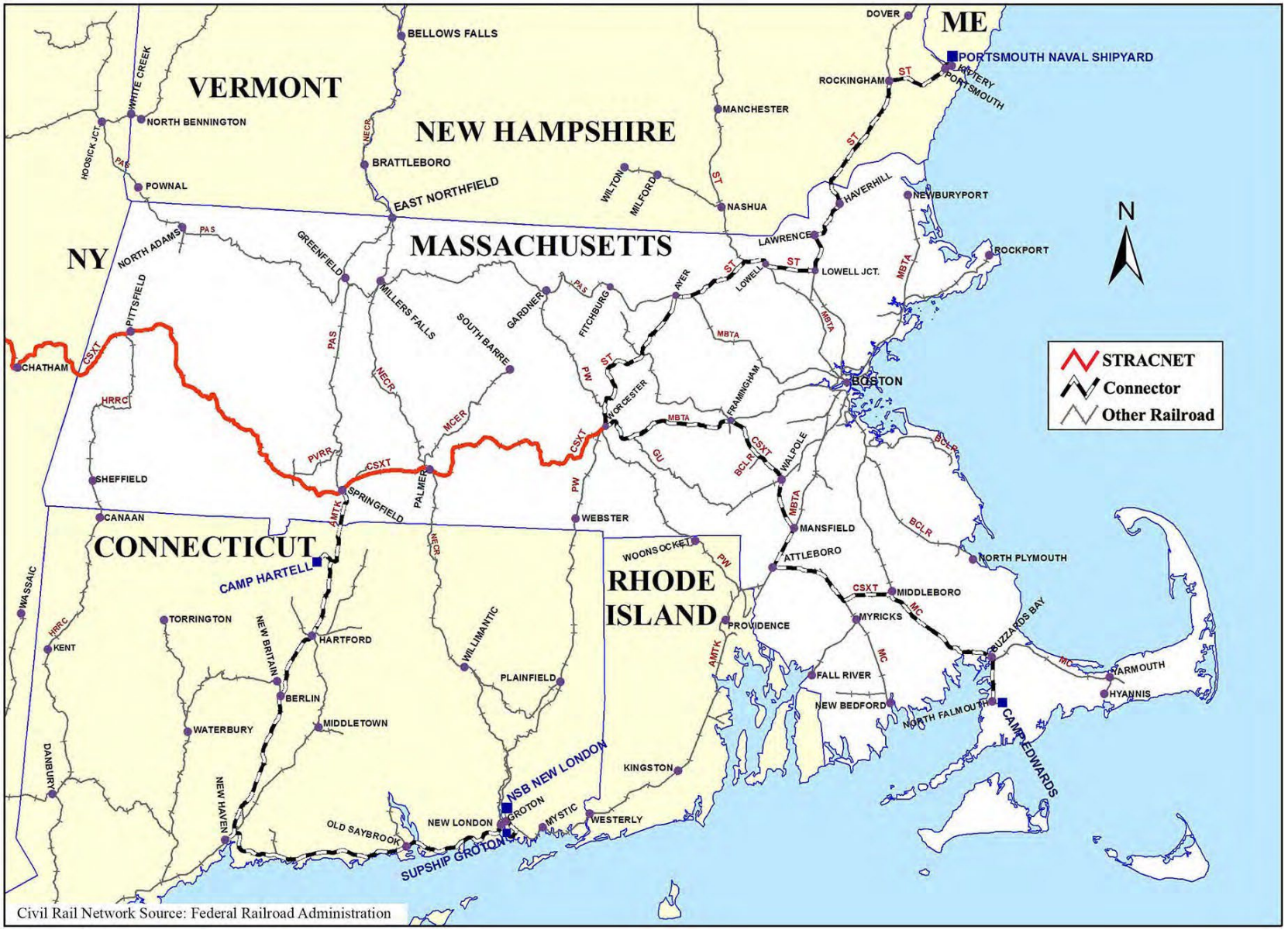
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


VERMONT
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NEW ORLEANS
PORT OF GULFPORT
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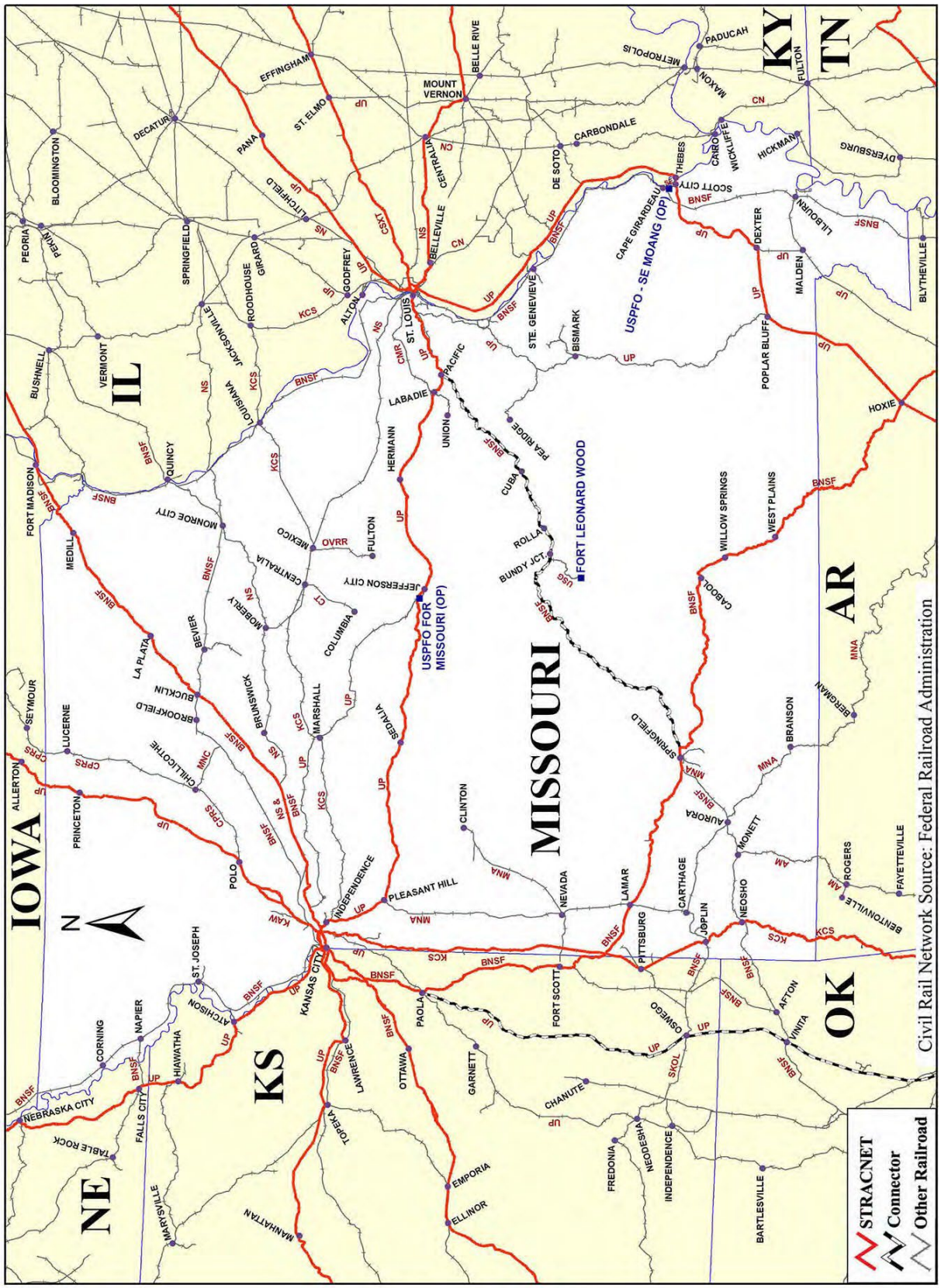
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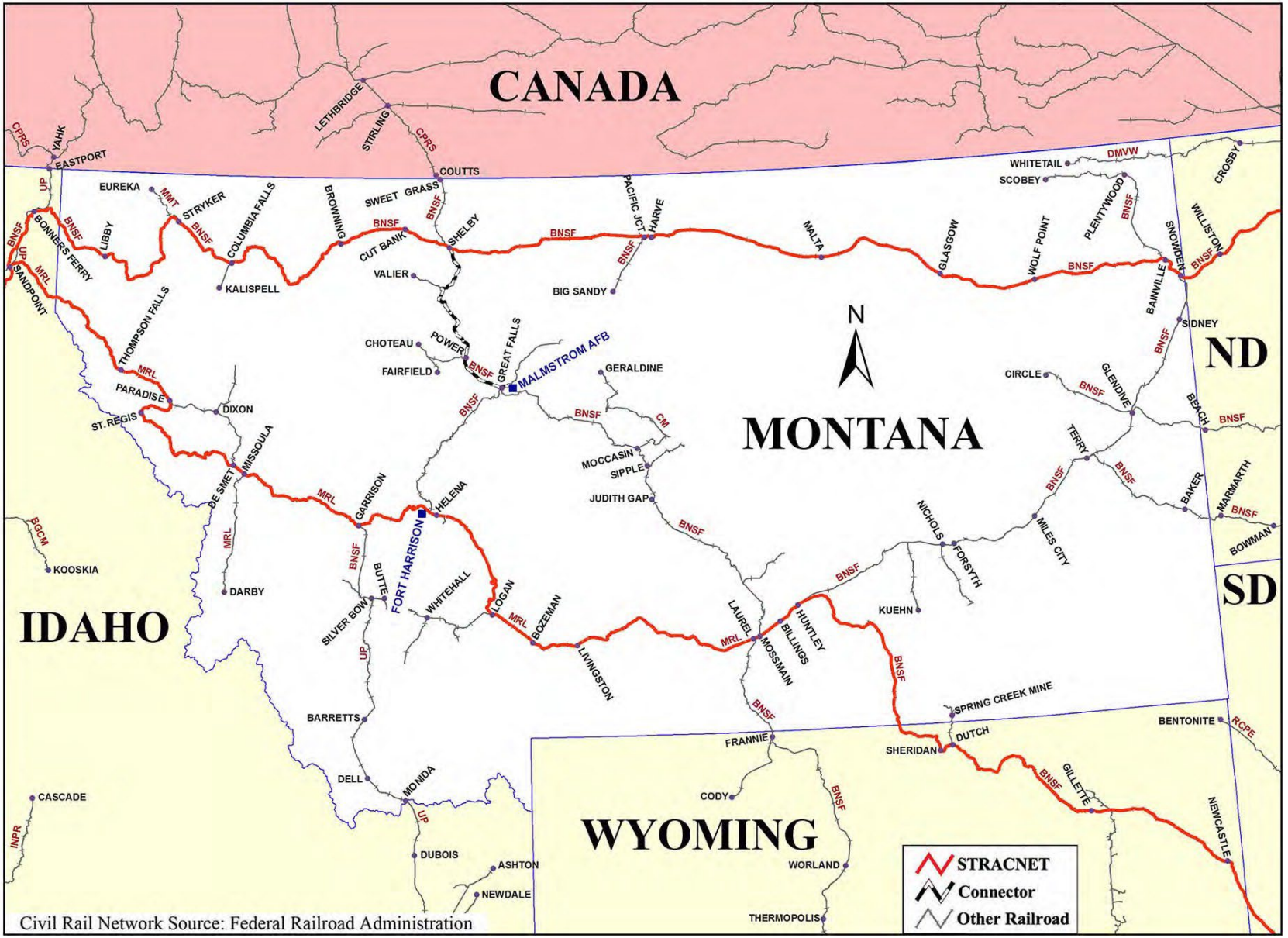
CANADA
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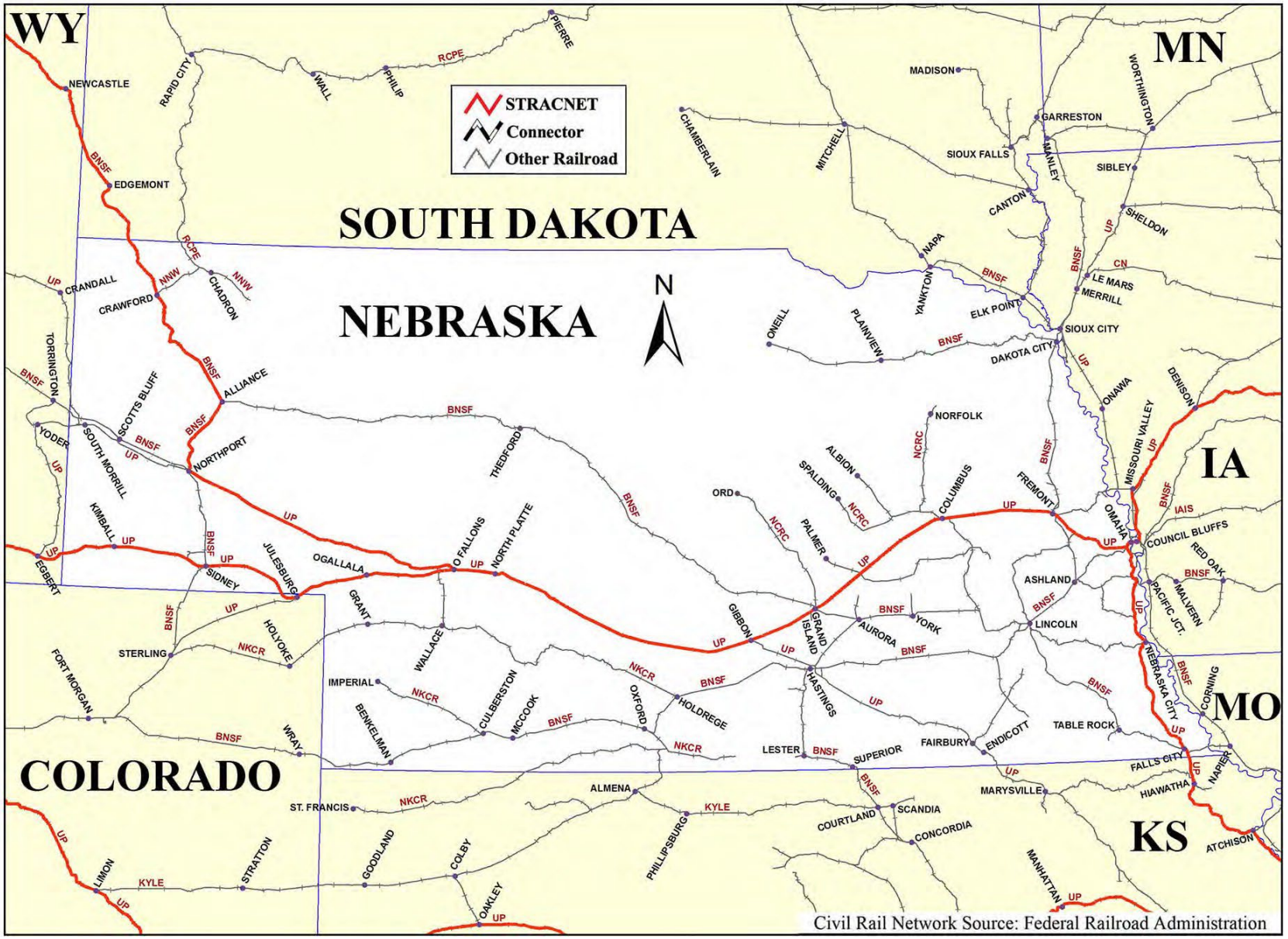
CPRS
EUREKA
STRYKER
LIBBY
BONNERS FERRY
SANDPOINT
KALISPELL
COLUMBIA FALLS
BROWNING
SWEET GRASS
CUT BANK
SHELBY
VALIER
BIG SANDY
PACIFIC JCT
HARVE
MALTA
GLASGOW
WOLF POINT
PLENTYWOOD
WHITETAIL
SCOBEY
CROSBY
WILLISTON
SNOWDEN
BAINVILLE
SIDNEY
CHOTEAU
POWER
FAIRFIELD
GREAT FALLS
MALMSTROM AFB
GERALDINE
CIRCLE
GLENDIVE
BEACH
THOMPSON FALLS
PARADISE
ST.REGIS
DIXON
MISSOULA
DE SMET
GARRISON
HELENA
MOCCASIN
SIPPLE
JUDITH GAP
TERRY
BAKER
MARMARTH
BOWMAN
NICHOLS
FORSYTH
MILES CITY
KUEHN
HUNTLEY
BILLINGS
MOSSMAIN
LAUREL
BOZEMAN
LOGAN
WHITEHALL
FORT HARRISON
BUTTE
SILVER BOW
DARBY
KOOSKIA
BGCM
LIVINGSTON
BARRETTS
DELL
MONIDA
CASCADE
INPR
DUBOIS
ASHTON
NEWDALE
CODY
WORLAND
THERMOPOLIS
FRANNIE
SPRING CREEK MINE
DUTCH
SHERIDAN
BENTONITE
RCPE
GILLETTE
NEWCASTLE
CM
DMVW
MMT
UP
MRL
BNSF
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


STRACNET
Connector
Other Railroad
SOUTH DAKOTA
NEBRASKA
COLORADO
WY
MN
IA
MO
KS
N
NEWCASTLE
EDGEMONT
RAPID CITY
WALL
PHILIP
PIERRE
RCPE
CHAMBERLAIN
MITCHELL
MADISON
GARRESTON
SIOUX FALLS
MANLEY
WORTHINGTON
SIBLEY
CANTON
SHELDON
NAPA
YANKTON
ELK POINT
LE MARS
MERRILL
SIOUX CITY
DAKOTA CITY
ONEILL
PLAINVIEW
ONAWA
DENISON
MISSOURI VALLEY
CRANDALL
CRAWFORD
CHADRON
TORRINGTON
YODER
SCOTTS BLUFF
SOUTH MORRILL
ALLIANCE
NORTHPORT
KIMBALL
EGBERT
SIDNEY
JULESBURG
OGALLALA
O FALLONS
NORTH PLATTE
THEDFORD
NORFOLK
ALBION
SPALDING
ORD
PALMER
COLUMBUS
FREMONT
OMAHA
COUNCIL BLUFFS
IAIS
RED OAK
MALVERN
PACIFIC JCT.
ASHLAND
LINCOLN
YORK
AURORA
GRAND ISLAND
GIBBON
HASTINGS
HOLDREGE
OXFORD
MCCOOK
CULBERSTON
BENKELMAN
WALLACE
GRANT
HOLYOKE
STERLING
FORT MORGAN
WRAY
IMPERIAL
NKCR
BNSF
UP
LESTER
SUPERIOR
FAIRBURY
ENDICOTT
TABLE ROCK
NEBRASKA CITY
CORNING
FALLS CITY
HIAWATHA
NAPIER
MARYSVILLE
ATCHISON
ALMENA
ST. FRANCIS
KYLE
PHILLIPSBURG
COURTLAND
SCANDIA
CONCORDIA
MANHATTAN
LIMON
STRATTON
GOODLAND
COLBY
OAKLEY
Civil Rail Network Source: Federal Railroad Administration

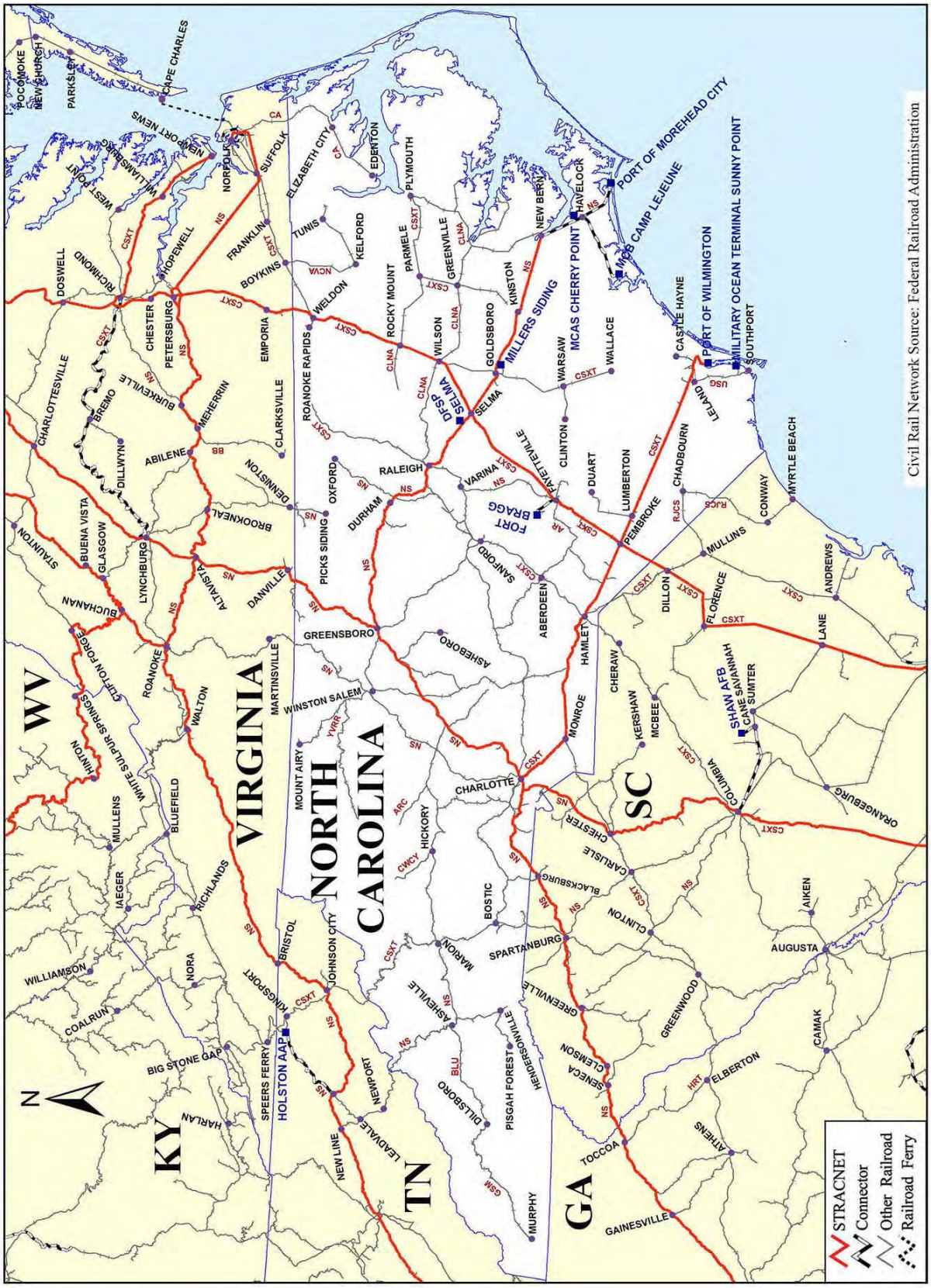
OREGON
IDAHO
NEVADA
UT
AZ
CALIFORNIA
N
LAKEVIEW
WINNEMUCCA
GERLACH
SIERRA ARMY DEPOT
HERLONG
FLANIGAN
RENO JCT
RENO
HAZEN
FALLON
WABUSKA
USG
HAWTHORNE ARMY DEPOT
CARLIN
ELKO
WELLS
COBRE
LUCIN
SHAFTER
WENDOVER
LUND
CALIENTE
MOAPA
MEAD LAKE
LAS VEGAS
HENDERSON
CIMA
KINGMAN
NEEDLES
TOPOCK
FRESNO
EXETER
HANFORD
BAKERSFIELD
SJVR
NAWCWD CHINA LAKE (OP)
TRONA
TRC
SEARLES
MOJAVE
BORON
EDWARDS AFB
BARSTOW
FORT IRWIN (OP)
MCLB BARSTOW
MANIX
UP
BNSF
USG
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

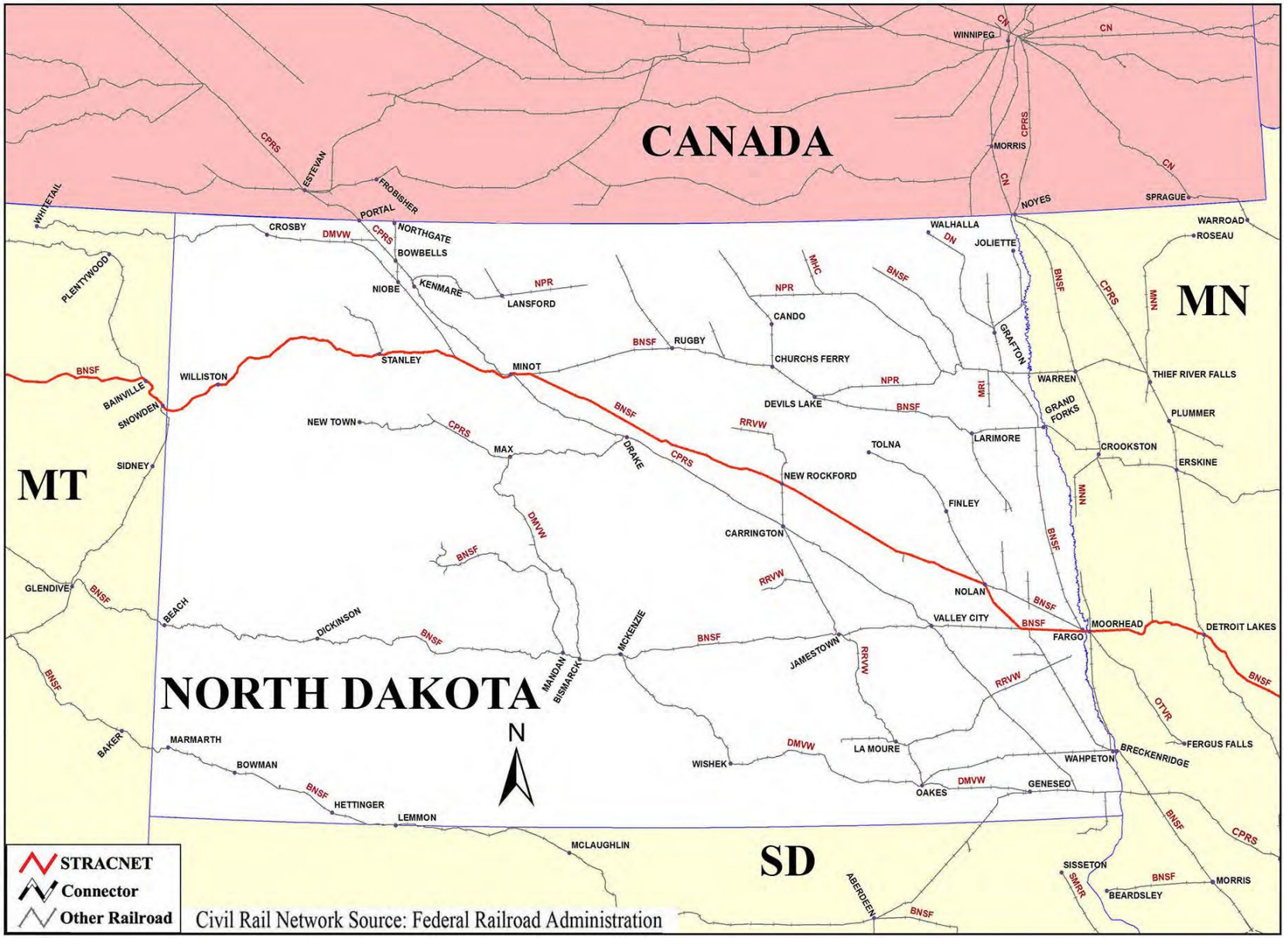
MONTREAL
ADIRONDACK JCT.
ST. JEANS
CPRS
CN
BROOKPORT
SHERBROOKE
SLQ
MEGANTIC
CANADA
CANTIC
ROUSES POINT
EAST ALBURGH
RICHFORD JCT.
CMQ
NEWPORT
NORTON
CPRS
ST ALBANS
VERMONT
SLR
ISLAND POND
NORTH STRATFORD
VTR
GROVETON
PLATTSBURGH
NECR
STRACNET
Connector
Other Railroad
SLR
ESSEX JCT.
BURLINGTON
ST JOHNSBURY
NHCR
BERLIN
WHITEFIELD
BETHEL
MONTPELIER JCT.
VTR
VTR
ME
WELLS RIVER
CSRX
VTR
LINCOLN
MIDDLEBURY
CONWAY
CASTLETON
NECR
N
VTR
RUTLAND
WHITE RIVER JCT.
OSSIPEE
PORTSMOUTH NAVAL SHIPYARD
WHITEHALL
CPRS
NHN
NORTH BERWICK
ST
TILTON
NY
CLAREMONT
NEGS
VTR
CHARLSTOWN
CONCORD
DOVER
BELLOWS FALLS
KITTERY
ROCKINGHAM
ST
WHITE CREEK
VTR
NEW
HAMPSHIRE
MANCHESTER
PORTSMOUTH
NORTH BENNINGTON
HOOSICK JCT.
PAS
NECR
WILTON
MILFORD
ST
HAVERHILL
BRATTLEBORO
NEWBURYPORT
POWNAL
EAST NORTHFIELD
NASHUA
LOWELL
LAWRENCE
NORTH ADAMS
GREENFIELD
PAS
MA
AYER
ST
LOWELL JCT.
MILLERS FALLS
Civil Rail Network Source: Federal Railroad Administration

SCRANTON AAP
PORT JERVIS
NY
WARWICK
MNJ
MNCW
CSXT
BREWSTER
DANBURY
NEW CANAAN
TOBYHANNA
NYSW
SUFFERN
EAST STROUDSBURG
DL
SPARTA JCT.
NYSW
NJT
CSXT
STAMFORD
RYE
PA
DENVILLE
NJT
NJT
LEHIGHTON
NS
ME
BARTLEY
ME
SUMMIT
EASTON
PHILLIPSBURG
GLADSTONE
NJT
NEWARK
LI
NEW YORK
HIGH BRIDGE
BOUND BROOK
NJT
CR
AMTK
PORT OF NEW YORK/NEW JERSEY
RCRY
BDRV
NS
BETHLEHEM
ALLENTOWN
MILFORD
LAMBERTVILLE
PORT READING
PERTH AMBOY
NS
BRW
NJT
USG
DOYLESTOWN
NHRR
CSXT
MORRISVILLE (JB MDL RAILHEAD)
PRINCETON
CR
JAMESBURG
RED BANK
NWS EARLE
NORRISTOWN
LANSDALE
SEPA
WOODBOURNE
CR
TRENTON
FARMINGDALE
ASBURY PARK
NS
NS
BORDENTOWN
NJT
NS
SEPA
CSXT
AMTK
CR
AMTK
NS
AMTK
NJT
MERCHANTVILLE
JOINT BASE MCGUIRE-DIX-LAKEHURST (OP)
BAY HEAD JCT.
NJT
MOUNT HOLLY
LAKEHURST
PHILADELPHIA
CAMDEN
NEW JERSEY
PORT OF PHILADELPHIA
WILMINGTON
CSXT
N
NEWARK
CR
NJT
CARNEYS POINT
CR
WINSLOW JCT.
NS
PORTER
SRNJ
SALEM
VINELAND
CR
NJT
BRIDGETON
MILLVILLE
PLEASANTVILLE
ATLANTIC CITY
TOWNSEND
WW
DCR
TUCKAHOE
CMSL
PALERMO
DE
DOVER
CAPE MAY
STRACNET
Connector
Other Railroad
Railroad Ferry
Civil Rail Network Source: Federal Railroad Administration

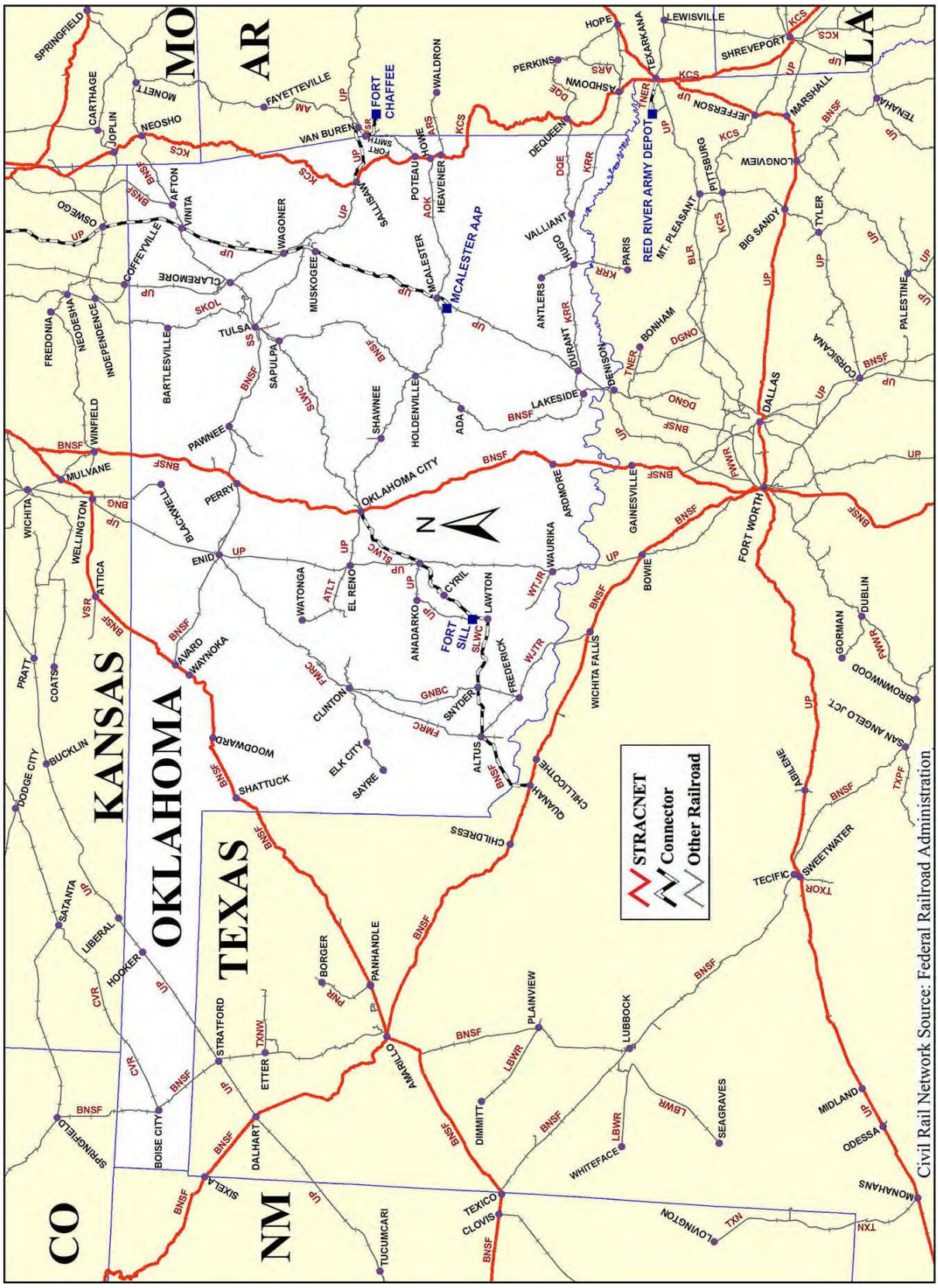
UTAH
COLORADO
KS
OK
ARIZONA
NEW MEXICO
TEXAS
MEXICO
STRACNET
Connector
Other Railroad
N
PIÑON CANYON MANEUVER SITE
TRINIDAD
ANTONITO
YORK CANYON
RATON
FRENCH
TRINCHERE
BOISE CITY
CVR
BNSF
SIXELA
STRATFORD
DALHART
ETTER
UP
AMARILLO
GALLUP
SANTA FE
LAS VEGAS
LAMY
NMRX
TUCUMCARI
SANTA ROSA
WINSLOW
HOLBROOK
NAVAJO
APA
SNOWFLAKE
SPRINGERVILLE
ALBUQUERQUE
ISLETA
BELEN
DALIES
VAUGHN
CLOVIS
TEXICO
DIMMITT
PLAINVIEW
WHITEFACE
LBWR
LUBBOCK
SEAGRAVES
SOCORRO
CARRIZOZO
ROSWELL
LOVINGTON
TXN
CARLSBAD
LOVING
MIDLAND
ODESSA
MONAHANS
PECOS
SIERRA BLANCA
MIAMI
CLIFTON
AZER
SAN MANUEL
TUCSON
BENSON
SPSR
CURTISS
NOGALES
FXE
BOWIE
LORDSBURG
DEMING
WHITEWATER
SW
RINCON
ORO GRANDE
FORT BLISS
EL PASO
Civil Rail Network Source: Federal Railroad Administration

CANADA
MONTREAL
ADIRONDACK JCT.
ST. JEANS
COTEAU
HUNTINGDON
CANTIC
EAST ALBURGH
ROUSES POINT
ST. ALBANS
MASSENA
NORWOOD
PLATTSBURGH
ESSEX JCT.
BURLINGTON
NECR
NEW YORK
OGDENSBURG
NYOG
BELLEVILLE
PHILADELPHIA
NEWTON FALLS
CALCIUM
WATERTOWN
FORT DRUM
LOWVILLE
MIDDLEBURY
VTR
CASTLETON
RUTLAND
NORTH CREEK
SNC
CLP
WHITEHALL
LYONS FALLS
RICHLAND
OSWEGO
TORONTO
OSHAWA
HAMILTON
ST. CATHARINES
NIAGARA FALLS
WEST SOMERSET
MEDINA
BROCKPORT
ROCHESTER
WEBSTER
WOLCOTT
CHILI JCT.
LOCKPORT
NEWARK
LYONS
VICTOR
GENEVA
WOODARD
REMSEN
ROME
UTICA
NNPP KESSELRING SITE (OP)
SARATOGA SPRINGS
BALLSTON SPA
SCHENECTADY
MECHANICVILLE
WHITE CREEK
NORTH BENNINGTON
POWNAL
VT
WELLAND
BUFFALO
DUNKIRK
NORTH JAVA
SYRACUSE
RICHFIELD JCT.
DELANSON
HOOSICK JCT
NORTH ADAMS
ALBANY
SHERBURNE
CORTLAND
SELKIRK
PITTSFIELD
GOWANDA
MACHIAS
DANSVILLE
HIMROD
ITHACA
CHENANGO FORKS
ONEONTA
CHATHAM
HUDSON
MA
ERIE
NORTH EAST
JAMESTOWN
BATH
CORNING
ELMIRA
OWEGO
BINGHAMTON
CANAAN
CORRY
OLEAN
EAST SALAMANCA
LAWRENCEVILLE
WAVERLY
SAYRE
KINGSTON
POUGHKEEPSIE
WASSAIC
CT
MOUNT JEWETT
PORT ALLEGANY
WELLSBORO JCT.
TOWANDA
CARBONDALE
HONESDALE
LACKAWAXEN
PENNSYLVANIA
SEE INSERT
BEACON
NJ
PORT JERVIS
SPARTA JCT.
BEACON
BREWSTER
DANBURY
NEW HAVEN
AMTK
SUFFERN
WARWICK
NEWARK
BOUND BROOK
PORT JEFFERSON
GREENPORT
MONTAUK
STAMFORD
RYE
NEW YORK
STRACNET
Connector
Other Railroad
Railroad Ferry
Civil Rail Network Source: Federal Railroad Administration

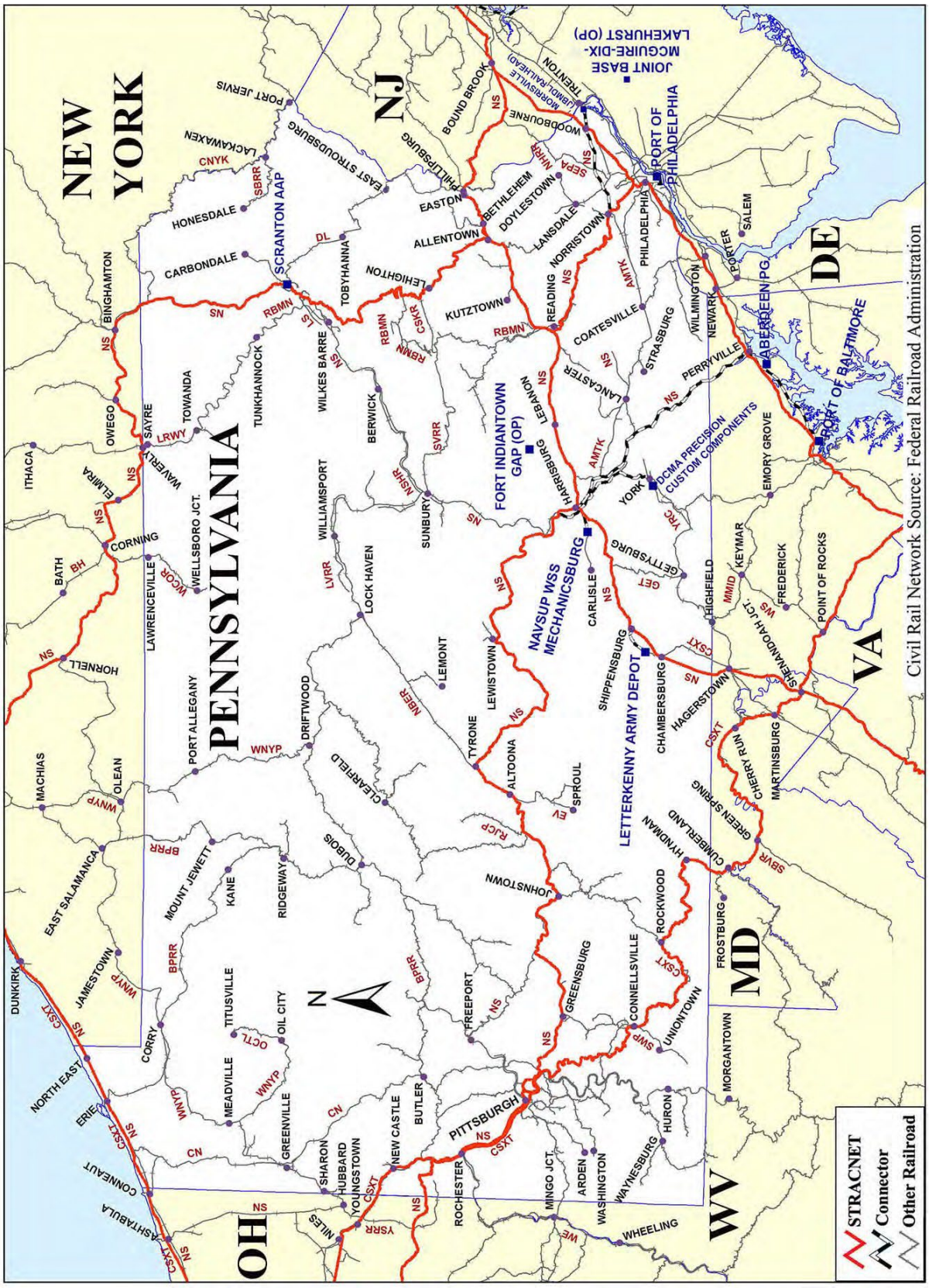

Civil Rail Network Source: Federal Railroad Administration
STRACNET
Connector
Other Railroad
Railroad Ferry
VIRGINIA
NORTH CAROLINA
SC
GA
TN
KY
WV
N
CAPE CHARLES
POCOMOKE
NEWSOMS
PARKSLEY
NEWPORT NEWS
WILLIAMSBURG
WEST POINT
NORFOLK
SUFFOLK
ELIZABETH CITY
EDENTON
PLYMOUTH
TUNIS
KELFORD
PARMELE
GREENVILLE
NEW BERN
HAVELOCK
PORT OF MOREHEAD CITY
MCB CAMP LEJEUNE
MCAS CHERRY POINT
MILLERS SIDING
KINSTON
GOLDSBORO
WILSON
ROCKY MOUNT
WELDON
ROANOKE RAPIDS
FRANKLIN
BOYKINS
HOPEWELL
RICHMOND
DOSWELL
CHESTER
PETERSBURG
EMPORIA
CLARKSVILLE
MEHERRIN
BURKEVILLE
BREMO
CHARLOTTESVILLE
ABILENE
DILLWYN
DENNISTON
BROOKNEAL
BUENA VISTA
GLASGOW
LYNCHBURG
STAUNTON
BUCHANAN
CLIFTON FORGE
COVINGTON
ALTAVISTA
DANVILLE
PICKS SIDING
OXFORD
DURHAM
RALEIGH
VARINA
FORT BRAGG
FAYETTEVILLE
SELMA
DSPG
CLINTON
DUART
WARSAW
WALLACE
CASTLE HAYNE
LELAND
CHADBOURN
PEMBROKE
LUMBERTON
MILITARY OCEAN TERMINAL SUNNY POINT
PORT OF WILMINGTON
SOUTHPORT
MYRTLE BEACH
CONWAY
MULLINS
DILLON
FLORENCE
ANDREWS
LANE
SANFORD
ABERDEEN
HAMLET
CHERAW
MONROE
ASHEBORO
GREENSBORO
WINSTON SALEM
MOUNT AIRY
MARTINSVILLE
ROANOKE
WALTON
HINTON
WHITE SULPHUR SPRINGS
MULLENS
BLUEFIELD
IAEGER
RICHLANDS
WILLIAMSON
COALRUN
NORA
BIG STONE GAP
HARLAN
SPEERS FERRY
HOLSTON AAP
KINGSPORT
BRISTOL
JOHNSON CITY
NEWPORT
LEADVALE
NEW LINE
MURPHY
GSM
BLU
DILLSBORO
PISGAH FOREST
HENDERSONVILLE
ASHEVILLE
MARION
BOSTIC
SPARTANBURG
GREENVILLE
SENECA
CLEMSON
TOCCOA
GAINESVILLE
ATHENS
ELBERTON
HRT
GREENWOOD
CLINTON
CARLISLE
BLACKSBURG
CHESTER
CHARLOTTE
HICKORY
ARC
CWCY
KERSHAW
MCBEE
CAMAK
AIKEN
AUGUSTA
SHAW AFB
CANE
SAVANNAH
SUMTER
COLUMBIA
ORANGEBURG
CSXT
NS
CA
NOVA
CLNA
BB
AR
RJCS
USG
YVRR


CANADA
NORTH DAKOTA
MT
MN
SD
N
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
WINNIPEG
MORRIS
NOYES
SPRAGUE
WARROAD
ROSEAU
WALHALLA
JOLIETTE
GRAFTON
THIEF RIVER FALLS
WARREN
GRAND FORKS
PLUMMER
CROOKSTON
ERSKINE
LARIMORE
TOLNA
DEVILS LAKE
CANDO
CHURCHS FERRY
RUGBY
MINOT
STANLEY
WILLISTON
BAINVILLE
SNOWDEN
PLENTYWOOD
SIDNEY
NEW TOWN
MAX
DRAKE
NEW ROCKFORD
FINLEY
CARRINGTON
NOLAN
VALLEY CITY
FARGO
MOORHEAD
DETROIT LAKES
FERGUS FALLS
BRECKENRIDGE
WAHPETON
GENESEO
OAKES
LA MOURE
WISHEK
JAMESTOWN
MANDAN
BISMARCK
MCKENZIE
DICKINSON
BEACH
GLENDIVE
BAKER
MARMARTH
BOWMAN
HETTINGER
LEMMON
MCLAUGHLIN
ABERDEEN
SISSETON
BEARDSLEY
MORRIS
CROSBY
NORTHGATE
BOWBELLS
NIOBE
KENMARE
LANSFORD
PORTAL
FROBISHER
ESTEVAN
WHITETAIL
CPRS
CN
BNSF
DMVW
NPR
MHC
DN
MRI
MNN
SMRR
OTVR
RRVW

Civil Rail Network Source: Federal Railroad Administration


STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
KANSAS
OKLAHOMA
TEXAS
MO
AR
LA
NM
CO
MCALESTER AAP
FORT CHAFFEE
FORT SILL
RED RIVER ARMY DEPOT
OKLAHOMA CITY
FORT WORTH
DALLAS
AMARILLO
LUBBOCK
ABILENE
SWEETWATER
WICHITA FALLS
LAWTON
ENID
PERRY
PONCA CITY
BARTLESVILLE
TULSA
MUSKOGEE
SPRINGFIELD
JOPLIN
FAYETTEVILLE
TEXARKANA
SHREVEPORT
LONGVIEW
TYLER
MARSHALL
DENISON
DURANT
ARDMORE
GAINESVILLE
BONHAM
PARIS
ATLANTA
LIBERAL
HOOKER
GUYMON
DODGE CITY
PRATT
BUCKLIN
WICHITA
WELLINGTON
ATTICA
MULVANE
WINFIELD
COFFEYVILLE
INDEPENDENCE
CHANUTE
OSWEGO
CHILDRESS
QUANAH
PANHANDLE
BORGER
PLAINVIEW
LEVELLAND
SEAGRAVES
MIDLAND
ODESSA
MONAHANS
PECOS
TEXICO
CLOVIS
TUCUMCARI
DALHART
STRATFORD
BOISE CITY
SPRINGFIELD
SIXELA
ETTER
WOODWARD
SHATTUCK
ELK CITY
SAYRE
ALTUS
CLINTON
SNYDER
ANADARKO
WATONGA
EL RENO
CYRIL
WAURIKA
FREDERICK
WAYNOKA
AVARD
BLACKWELL
PAWNEE
SAPULPA
SHAWNEE
HOLDENVILLE
ADA
VALLIANT
ANTLERS
HUGO
IDABEL
DEQUEEN
ASHDOWN
PERKINS
HOPE
WALDRON
HEAVENER
POTEAU
VAN BUREN
FORT SMITH
SALLISAW
WAGONER
VINITA
AFTON
NEOSHO
MONETT
CARTHAGE
FREDONIA
NEODESHA
CLAREMORE
PITTSBURG
MT. PLEASANT
BIG SANDY
JEFFERSON
TENAHA
PALESTINE
CORSICANA
GORMAN
DUBLIN
BROWNWOOD
SAN ANGELO JCT.
WHITEFACE
LOVINGTON
BOWIE
LEWISVILLE
KCS
UP
BNSF
AM
ARS
DQE
KRR
TNER
DGNO
SKOL
SLWC
FWWR
GNBC
FMRC
PNR
TXNW
LBWR
TXOR
TXPF
TXN
NXL
VSR
BNG
ATLT
WTJR
AOK
BLR

WA
OREGON
IDAHO
NEVADA
CA
CENTRALIA
MORTON
KELSO
ASTORIA
CHELATCHIE
VANCOUVER
PORTLAND
SALEM
MILL CITY
TOLEDO
CORVALLIS
ALBANY
EUGENE
COTTAGE GROVE
COOS BAY
COQUILLE
ROSEBURG
GRANTS PASS
MEDFORD
ASHLAND
YREKA
MONTAGUE
BLACK BUTTE
CHEMULT
KLAMATH FALLS
LAKEVIEW
ALTURAS
BEND
REDMOND
PRINEVILLE JCT.
PRINEVILLE
MADRAS
THE DALLES
OREGON TRUMK JCT.
BINGEN
WISHRAM
ARLINGTON
HINKLE
POMONA
YAKIMA
YAKIMA TRAINING CENTER (OP)
WHITE SWAN
TOPPENISH
GIBBON
PASCO
CONNELL
WALLULA
WALLA WALLA
PCC
AYER
DAYTON
MOSCOW
LEWISTON
KOOSKIA
PENDLETON
LA GRANDE
BAKER
ELGIN
HUNTINGTON
CASCADE
VALE
PAYETTE
WILDER
NAMPA
BOISE
ORCHARD
ORCHARD COMBAT TRAINING CENTER
MOUNTAIN HOME
N
BNSF
UP
PNWR
PVJR
AERC
CBR
CORP
COP
MH
INPR
WURR
GOOS
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


NEW YORK
PENNSYLVANIA
NJ
DE
MD
VA
WV
OH
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
SCRANTON AAP
FORT INDIANTOWN GAP (OP)
NAVSUP WSS MECHANICSBURG
LETTERKENNY army DEPOT
JOINT BASE MCGUIRE-DIX-LAKEHURST (OP)
PORT OF PHILADELPHIA
PORT OF BALTIMORE
ABERDEEN PG
DCMA PRECISION CUSTOM COMPONENTS
PITTSBURGH
ERIE
BUFFALO
ROCHESTER
SYRACUSE
BINGHAMTON
ELMIRA
CORNING
WILLIAMSPORT
HARRISBURG
YORK
LANCASTER
READING
PHILADELPHIA
ALLENTOWN
EASTON
SCRANTON
WILKES BARRE
ALTOONA
JOHNSTOWN
GREENSBURG
CONNELLSVILLE
UNIONTOWN
MORGANTOWN
WHEELING
CHAMBERSBURG
HAGERSTOWN
MARTINSBURG
FREDERICK
BALTIMORE
WILMINGTON
NEWARK
TRENTON
BOUND BROOK
PHILLIPSBURG
EAST STROUDSBURG
PORT JERVIS
HONESDALE
CARBONDALE
LACKAWAXEN
OWEGO
SAYRE
TOWANDA
WAVERLY
ITHACA
BATH
HORNELL
WELLSBORO JCT.
LAWRENCEVILLE
TUNKHANNOCK
BERWICK
SUNBURY
LOCK HAVEN
LEWISTOWN
TYRONE
LEMONT
DRIFTWOOD
PORT ALLEGANY
CLEARFIELD
DUBOIS
RIDGEWAY
KANE
MOUNT JEWETT
EAST SALAMANCA
OLEAN
MACHIAS
JAMESTOWN
CORRY
TITUSVILLE
OIL CITY
MEADVILLE
GREENVILLE
SHARON
HUBBARD
YOUNGSTOWN
NILES
NEW CASTLE
BUTLER
FREEPORT
ROCKWOOD
HURON
ARDEN
WASHINGTON
WAYNESBURG
MINGO JCT.
ROCHESTER
CONNEAUT
ASHTABULA
NORTH EAST
DUNKIRK
SHIPPENSBURG
CARLISLE
GETTYSBURG
HIGHFIELD
KEYMAR
SHENANDOAH JCT.
POINT OF ROCKS
EMORY GROVE
PERRYVILLE
STRASBURG
COATESVILLE
NORRISTOWN
LANSDALE
DOYLESTOWN
BETHLEHEM
WOODBOURNE
MORRISVILLE
PORTER
SALEM
FROSTBURG
CUMBERLAND
GREEN SPRING
CHERRY RUN
HYNDMAN
SPROUL
LEHIGHTON
TOBYHANNA
KUTZTOWN
LEBANON
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CSXT
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BPRR
WNYP
LRWY
BH
WCOR
LVRR
NBER
RJCP
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YRC
MMID
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CSKR
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SVRR
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AMTK
CNYK
SBRR
OCTL

WEBSTER
PW
MBTA
MANSFIELD
WOONSOCKET
PW
MBTA
CSXT
ATTLEBORO
N
PROVIDENCE
MA
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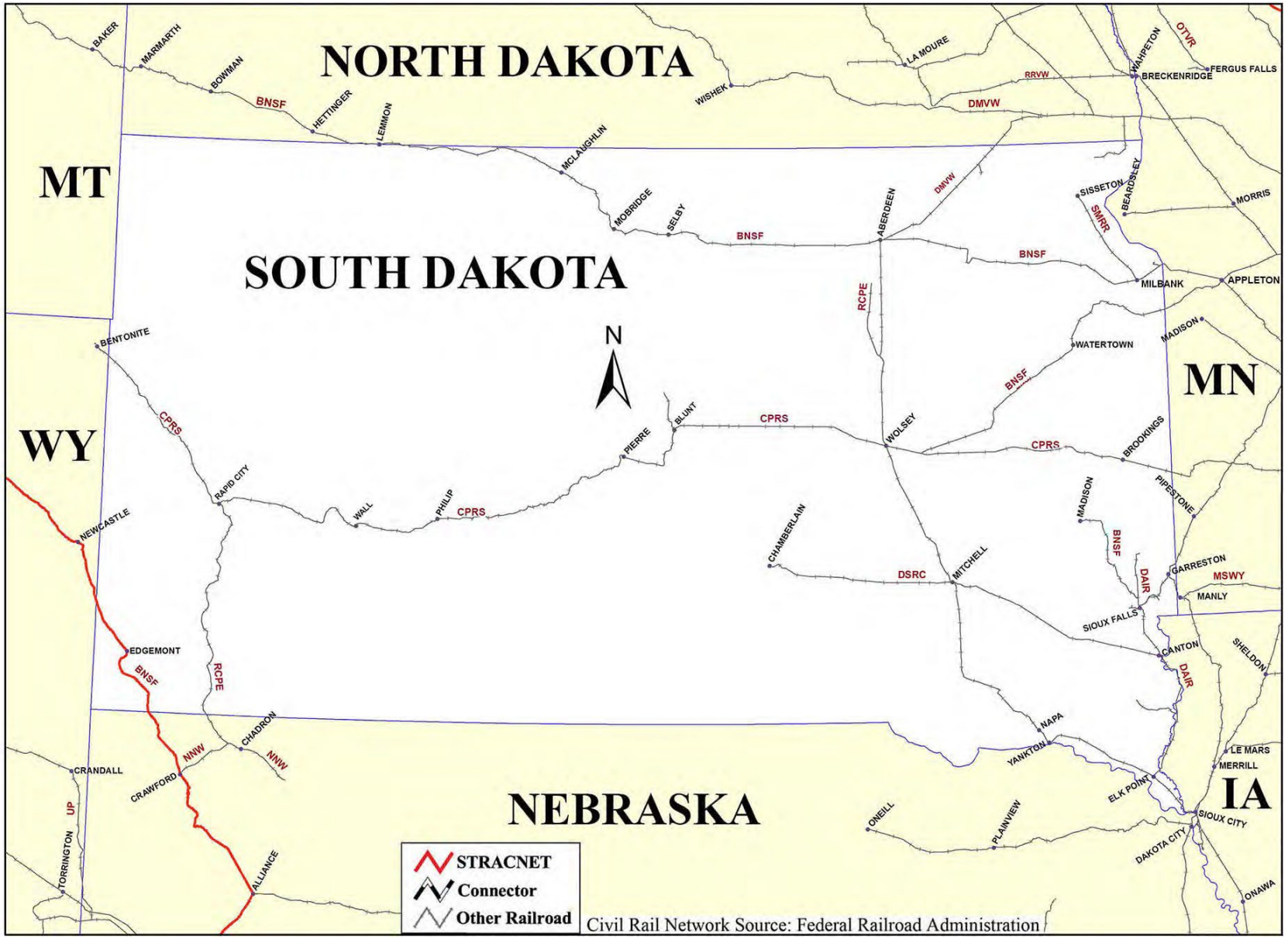
RHODE
ISLAND
PW
PLAINFIELD
FALL RIVER
CT
AMTK
KINGSTON
MYSTIC
AMTK
WESTERLY
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

NC
SOUTH CAROLINA
GEORGIA
N
DILLSBORO
HENDERSONVILLE
BOSTIC
PISGAH FOREST
BLACKSBURG
SPARTANBURG
GREENVILLE
SENECA
CLEMSON
TOCCOA
BOWERSVILLE
BELTON
GREENWOOD
CLINTON
CHESTER
CARLISLE
CHARLOTTE
MONROE
ABERDEEN
HAMLET
FORT BRAGG
FAYETTEVILLE
CLINTON
WARSAW
DUART
WALLACE
LUMBERTON
PEMBROKE
CASTLE HAYNE
CHERAW
KERSHAW
MCBEE
BENNETTSVILLE
DILLON
FLORENCE
MULLINS
CHADBOURN
LELAND
PORT OF WILMINGTON
SOUTHPORT
CONWAY
MYRTLE BEACH
BISHOPVILLE
FORT JACKSON (OP)
SHAW AFB
CANE SAVANNAH
COLUMBIA
SUMTER
ATHENS
ELBERTON
TRENTON
AUGUSTA
AIKEN
CAMAK
ORANGEBURG
LANE
ANDREWS
GEORGETOWN
PREGNALL
MILLEDGEVILLE
KAOLIN
WAYNESBORO
FAIRFAX
SYLVANIA
MIDVILLE
MILLEN
DUBLIN
SWAINSBORO
DOVER
VIDALIA
YEMASSEE
JOINT BASE CHARLESTON
DFSP CHARLESTON
PORT OF CHARLESTON
CHARLESTON
PORT OF SAVANNAH
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
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MCLAUGHLIN
MOBRIDGE
SELBY
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LA MOURE
WAHPETON
BRECKENRIDGE
FERGUS FALLS
OTVR
RRVW
DMVW
ABERDEEN
SISSETON
BEARDSLEY
MORRIS
SMRR
MILBANK
APPLETON
WATERTOWN
MADISON
BENTONITE
RAPID CITY
WALL
PHILIP
PIERRE
BLUNT
WOLSEY
BROOKINGS
PIPESTONE
CHAMBERLAIN
MITCHELL
GARRESTON
MSWY
MANLY
SIOUX FALLS
CANTON
SHELDON
NAPA
YANKTON
LE MARS
MERRILL
ELK POINT
SIOUX CITY
ONEILL
PLANVIEW
DAKOTA CITY
ONAWA
NEWCASTLE
EDGEMONT
CRAWFORD
CHADRON
CRANDALL
TORRINGTON
ALLIANCE
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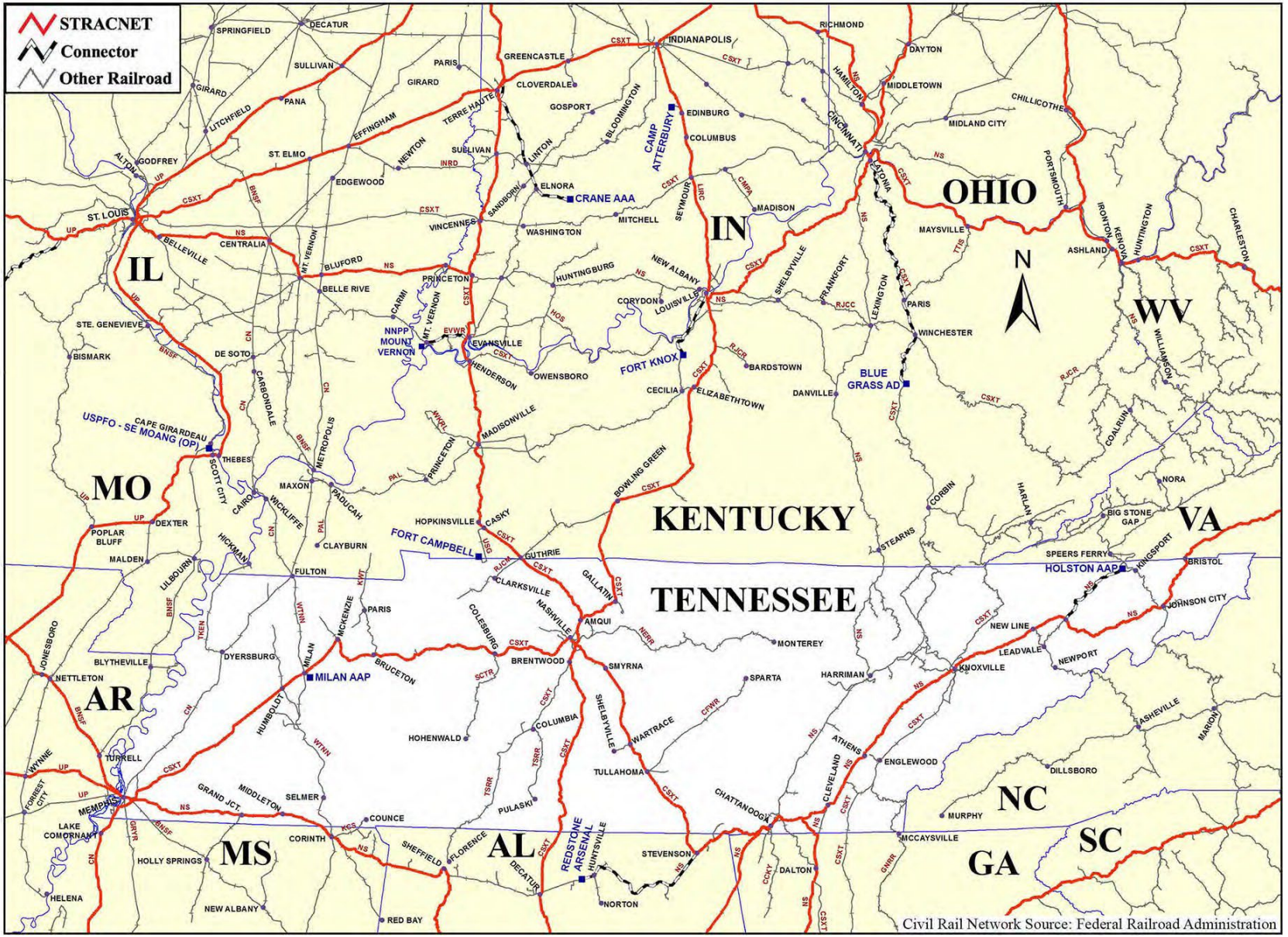
UP
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration


STRACNET
Connector
Other Railroad
SPRINGFIELD
DECATUR
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PARIS
GIRARD
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INDIANAPOLIS
RICHMOND
DAYTON
CLOVERDALE
GOSPORT
EDINBURG
COLUMBUS
MIDDLETOWN
CHILLICOTHE
MIDLAND CITY
CINCINNATI
LITCHFIELD
PANA
EFFINGHAM
TERRE HAUTE
BLOOMINGTON
CAMP ATTERBURY
ST. ELMO
NEWTON
SULLIVAN
LINTON
ALTON
GODFREY
EDGEWOOD
ELNORA
CRANE AAA
SANDBORN
SEYMOUR
MADISON
PORTSMOUTH
ST. LOUIS
VINCENNES
WASHINGTON
MITCHELL
IL
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OHIO
MAYSVILLE
ASHLAND
IRONTON
KENOVA
HUNTINGTON
CHARLESTON
BELLEVILLE
CENTRALIA
MT. VERNON
BLUFORD
PRINCETON
HUNTINGBURG
NEW ALBANY
SHELBYVILLE
FRANKFORT
LEXINGTON
PARIS
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WILLIAMSON
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HENDERSON
OWENSBORO
CORYDON
LOUISVILLE
FORT KNOX
BARDSTOWN
CECILIA
ELIZABETHTOWN
DANVILLE
BLUE GRASS AD
CARBONDALE
METROPOLIS
USPFO - SE MOANG (OP)
CAPE GIRARDEAU
THEBES
SCOTT CITY
MADISONVILLE
PRINCETON
BOWLING GREEN
CORBIN
HARLAN
COALRUN
NORA
BIG STONE GAP
VA
MO
MAXON
PADUCAH
CAIRO
WICKLIFFE
POPLAR BLUFF
DEXTER
HOPKINSVILLE
CASKY
KENTUCKY
STEARNS
HICKMAN
CLAYBURN
FORT CAMPBELL
GUTHRIE
SPEERS FERRY
HOLSTON AAP
KINGSPORT
BRISTOL
MALDEN
LILBOURN
FULTON
CLARKSVILLE
GALLATIN
JOHNSON CITY
PARIS
MCKENZIE
COLESBURG
NASHVILLE
AMQUI
TENNESSEE
NEW LINE
LEADVALE
NEWPORT
KNOXVILLE
JONESBORO
BLYTHEVILLE
DYERSBURG
MILAN
BRUCETON
BRENTWOOD
SMYRNA
MONTEREY
SPARTA
HARRIMAN
NETTLETON
AR
MILAN AAP
HOHENWALD
COLUMBIA
SHELBYVILLE
WARTRACE
ATHENS
ASHEVILLE
MARION
ENGLEWOOD
DILLSBORO
TURRELL
WYNNE
FORREST CITY
MEMPHIS
GRAND JCT.
MIDDLETON
SELMER
PULASKI
TULLAHOMA
CHATTANOOGA
CLEVELAND
NC
MURPHY
LAKE COMORANT
HOLLY SPRINGS
CORINTH
COUNCE
SHEFFIELD
FLORENCE
DECATUR
REDSTONE ARSENAL
HUNTSVILLE
STEVENSON
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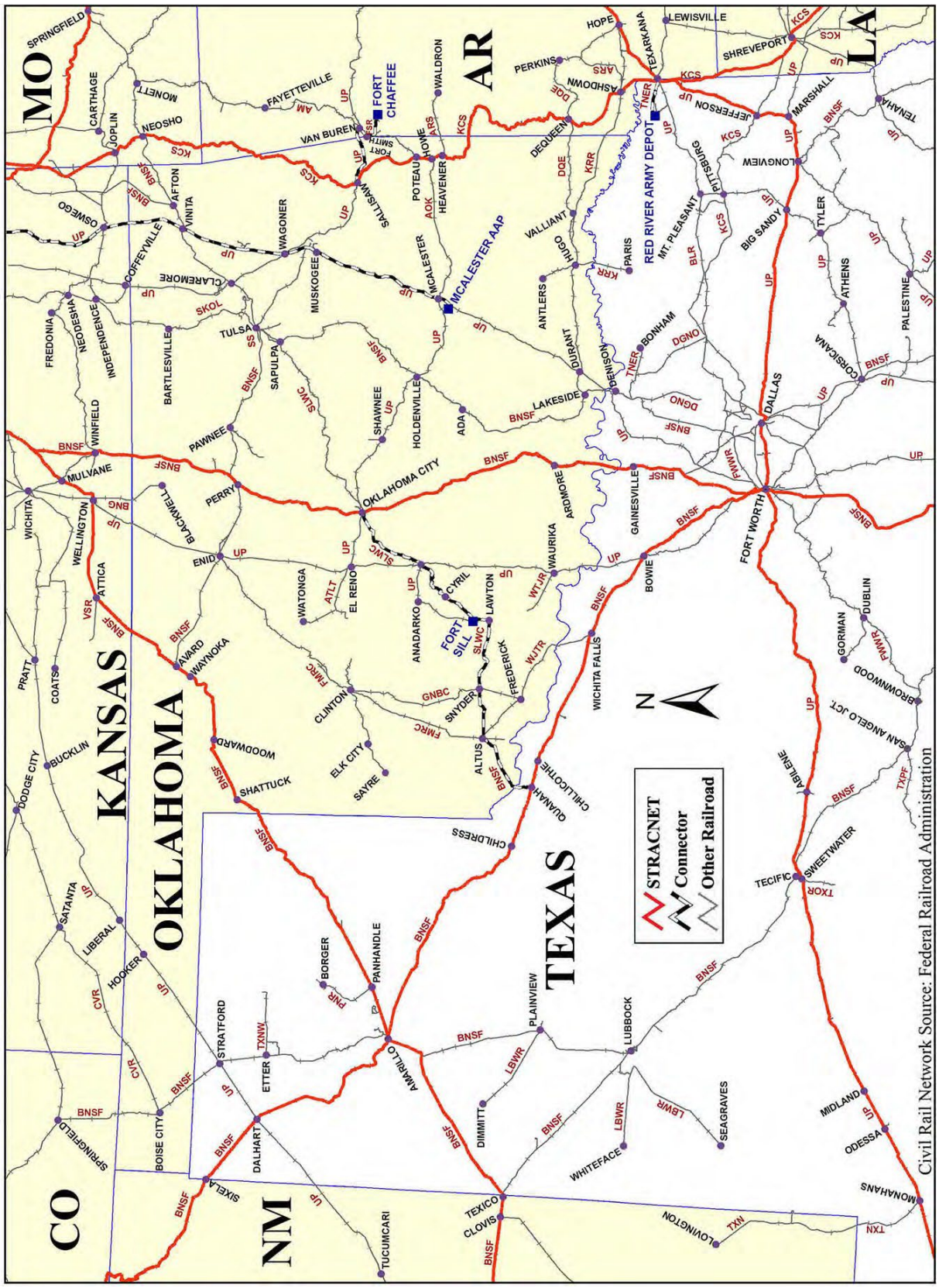
HELENA
NEW ALBANY
RED BAY
NORTON
Civil Rail Network Source: Federal Railroad Administration


MO
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STRACNET
Connector
Other Railroad
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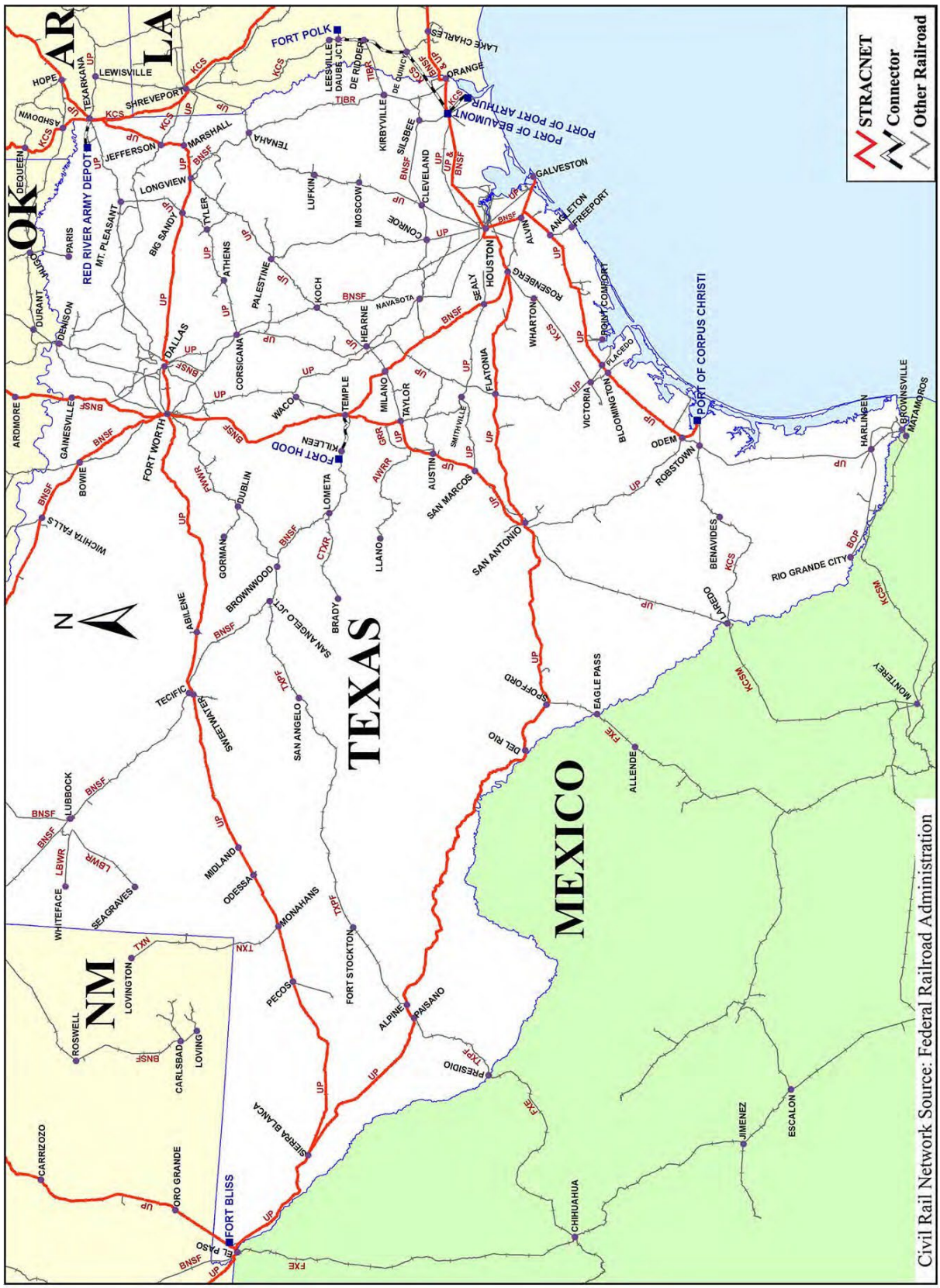
Civil Rail Network Source: Federal Railroad Administration
FORT CHAFFEE
MCALESTER AAP
RED RIVER ARMY DEPOT
FORT SILL
SPRINGFIELD
CARTHAGE
JOPLIN
MONETT
NEOSHO
FAYETTEVILLE
VAN BUREN
WALDRON
HOPE
PERKINS
ASHDOWN
TEXARKANA
LEWISVILLE
SHREVEPORT
MARSHALL
JEFFERSON
LONGVIEW
TENAHA
AFTON
VINITA
OSWEGO
COFFEYVILLE
CLAREMORE
WAGONER
MUSKOGEE
SALLISAW
POTEAU
HEAVENER
DEQUEEN
VALLIANT
ANTLERS
DURANT
PARIS
MT. PLEASANT
BIG SANDY
TYLER
ATHENS
PALESTINE
FREDONIA
NEODESHA
INDEPENDENCE
BARTLESVILLE
TULSA
SAPULPA
HOLDENVILLE
SHAWNEE
ADA
LAKESIDE
DENISON
BONHAM
CORSICANA
DALLAS
WINFIELD
PAWNEE
MULVANE
WICHITA
WELLINGTON
BLACKWELL
PERRY
ENID
OKLAHOMA CITY
ARDMORE
GAINESVILLE
FORT WORTH
ATTICA
AVARD
WAYNOKA
WOODWARD
SHATTUCK
WATONGA
EL RENO
CYRIL
LAWTON
ANADARKO
WAURIKA
BOWIE
DUBLIN
GORMAN
BROWNWOOD
SAN ANGELO JCT
ABILENE
SWEETWATER
TECIFIC
PRATT
COATS
BUCKLIN
DODGE CITY
CLINTON
SNYDER
FREDERICK
ALTUS
ELK CITY
SAYRE
QUANAH
CHILLICOTHE
WICHITA FALLS
CHILDRESS
SATANTA
LIBERAL
HOOKER
BORGER
PANHANDLE
AMARILLO
STRATFORD
ETTER
DALHART
BOISE CITY
SPRINGFIELD
SIXELA
TUCUMCARI
PLAINVIEW
LUBBOCK
DIMMITT
WHITEFACE
SEAGRAVES
MIDLAND
ODESSA
MONAHANS
TEXICO
CLOVIS
LOVINGTON


STRACNET
Connector
Other Railroad
TEXAS
MEXICO
NM
OK
AR
LA
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FORT POLK
LAKE CHARLES
ORANGE
PORT OF BEAUMONT
PORT OF PORT ARTHUR
GALVESTON
ANGLETON
FREEPORT
PORT OF CORPUS CHRISTI
BROWNSVILLE
MATAMOROS
HARLINGEN
RIO GRANDE CITY
BENAVIDES
LAREDO
EAGLE PASS
DEL RIO
SPOFFORD
ALLENDE
MONTERREY
PIEDRAS NEGRAS
PRESIDIO
OJINAGA
JIMENEZ
ESCALON
CHIHUAHUA
SIERRA BLANCA
FORT BLISS
EL PASO
CARRIZOZO
ORO GRANDE
ALPINE
MARFA
FORT STOCKTON
PECOS
MONAHANS
ODESSA
MIDLAND
SWEETWATER
ABILENE
SAN ANGELO
BRADY
BROWNWOOD
GORMAN
DUBLIN
LOMETA
FORT WORTH
DALLAS
GAINESVILLE
ARDMORE
WICHITA FALLS
BOWIE
DENISON
DURANT
IDABEL
PARIS
MT. PLEASANT
RED RIVER ARMY DEPOT
TEXARKANA
HOPE
ASHDOWN
DEQUEEN
LEWISVILLE
SHREVEPORT
MARSHALL
JEFFERSON
LONGVIEW
BIG SANDY
TYLER
ATHENS
PALESTINE
CORSICANA
WACO
TEMPLE
KILLEEN
FORT HOOD
MILANO
TAYLOR
AUSTIN
SAN MARCOS
SAN ANTONIO
LLANO
KOCH
HEARNE
NAVASOTA
SEALY
HOUSTON
ROSENBERG
WHARTON
VICTORIA
BLOOMINGTON
PORT LAVACA
PLACEDO
POINT COMFORT
FLATONIA
SMITHVILLE
ROBSTOWN
ODEM
LUFKIN
MOSCOW
CONROE
CLEVELAND
KIRBYVILLE
SILSBEE
DE QUINCY
LEESVILLE
DAUBE JCT
DE RIDDER
TENAHA
LOVINGTON
ROSWELL
CARLSBAD
LOVING
WHITEFACE
SEAGRAVES
LUBBOCK
TECIFIC
SMEETWATER
SAN ANGELO
BRADY
LLANO
SAN MARCOS
AUSTIN
KILLEEN
FORT HOOD
WACO
TEMPLE
MILANO
TAYLOR
FLATONIA
SMITHVILLE
VICTORIA
BLOOMINGTON
PORT LAVACA
PLACEDO
POINT COMFORT
ROBSTOWN
ODEM
HARLINGEN
BROWNSVILLE
MATAMOROS

WENDELL
UP
EIRR
MINIDOKA
BUHL
TWIN FALLS
RUPERT
POCATELLO
UP
MCCAMMON
UP
ALEXANDER
CONDA
IDAHO
WYOMING
MALAD
UP
CACHE JCT
UP
PRESTON
UP
KEMMERER
GRANGER
UP
ROCK SPRINGS
CORINNE
BRIGHAM CITY
COBRE
UP
LUCIN
UP
UP
OGDEN
EVANSTON
UP
UP
GREEN RIVER
ECHO
UP
HILL AFB
UP
SHAFTER
UP
WENDOVER
UP
SALT LAKE CITY
SBG
CO
TOOELE ARMY DEPOT
UP
ATK THIOKOL (MAGNA)
PROVO
SPRINGVILLE
N
UP
UP
UTAH RAILWAY JUNCTION
NEPHI
HELPER
NV
LYNNDYL
UP
UTAH
MOHRLAND
UP
DELTA
UTAH
UP
BRENDEL
UP
THOMPSON
UP
GRAND JUNCTION
UP
POTASH
MILFORD
LUND
UP
CALIENTE
CMBR
UP
CEDAR CITY
IRON MOUNTAIN
UP
NM
ARIZONA
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

CANADA
VERMONT
NEW HAMPSHIRE
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Connector
Other Railroad
N
MONTREAL
ADIRONDACK JCT.
ST. JEANS
MEGANTIC
SHERBROOKE
BROOKPORT
CANTIC
ROUSES POINT
EAST ALBURGH
RICHFORD JCT.
NEWPORT
NORTON
ST ALBANS
ISLAND POND
NORTH STRATFORD
GROVETON
PLATTSBURGH
ESSEX JCT.
BURLINGTON
ST JOHNSBURY
BERLIN
WHITEFIELD
BETHEL
MONTPELIER JCT.
WELLS RIVER
LINCOLN
CONWAY
MIDDLEBURY
CASTLETON
RUTLAND
WHITE RIVER JCT.
OSSIPEE
WHITEHALL
TILTON
CLAREMONT
CHARLSTOWN
CONCORD
DOVER
BELLOWS FALLS
WHITE CREEK
NORTH BENNINGTON
HOOSICK JCT.
BRATTLEBORO
WILTON
MILFORD
MANCHESTER
ROCKINGHAM
KITTERY
PORTSMOUTH NAVAL SHIPYARD
NORTH BERWICK
PORTSMOUTH
POWNAL
EAST NORTHFIELD
NASHUA
HAVERHILL
NEWBURYPORT
NORTH ADAMS
GREENFIELD
LAWRENCE
LOWELL
LOWELL JCT.
AYER
MILLERS FALLS
CPRS
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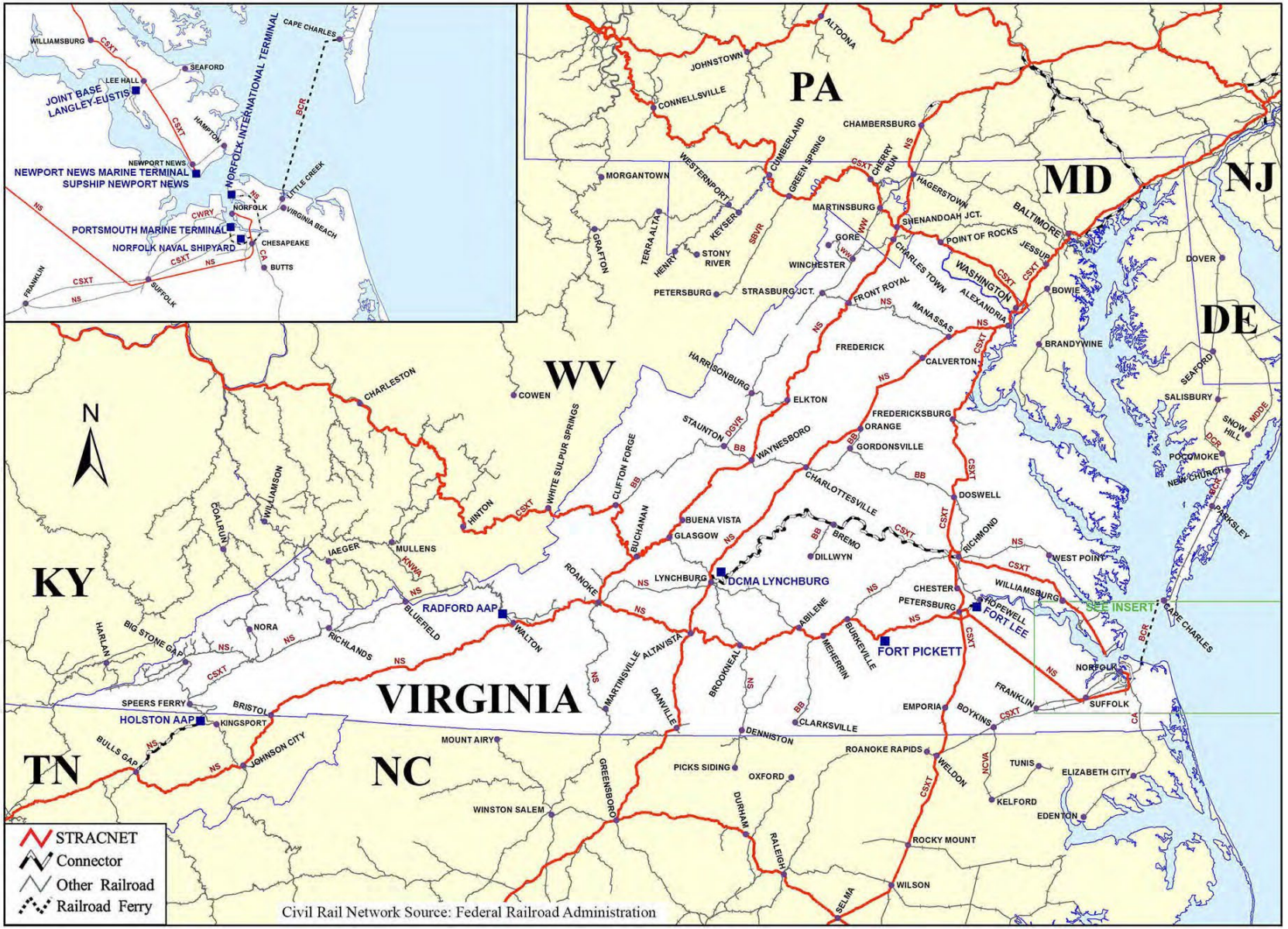
Civil Rail Network Source: Federal Railroad Administration


PA
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STRACNET
Connector
Other Railroad
Railroad Ferry
Civil Rail Network Source: Federal Railroad Administration
SEE INSERT
DCMA LYNCHBURG
RADFORD AAP
HOLSTON AAP
FORT PICKETT
JOINT BASE LANGLEY-EUSTIS
NEWPORT NEWS MARINE TERMINAL
SUPSHIP NEWPORT NEWS
PORTSMOUTH MARINE TERMINAL
NORFOLK NAVAL SHIPYARD
NORFOLK INTERNATIONAL TERMINAL
CAPE CHARLES
WILLIAMSBURG
SEAFORD
LEE HALL
HAMPTON
NEWPORT NEWS
NORFOLK
VIRGINIA BEACH
CHESAPEAKE
BUTTS
SUFFOLK
FRANKLIN
LITTLE CREEK
HAGERSTOWN
MARTINSBURG
SHENANDOAH JCT.
POINT OF ROCKS
BALTIMORE
WASHINGTON
ALEXANDRIA
BOWIE
BRANDYWINE
CALVERTON
FREDERICK
MANASSAS
FRONT ROYAL
STRASBURG JCT.
WINCHESTER
PETERSBURG
CHAMBERSBURG
CHERRY RUN
GREEN SPRING
CUMBERLAND
WESTERNPORT
MORGANTOWN
GRAFTON
TERRA ALTA
HENRY
STONY RIVER
KEYSER
JOHNSTOWN
CONNELLSVILLE
ALTOONA
HARRISONBURG
ELKTON
STAUNTON
WAYNESBORO
FREDERICKSBURG
ORANGE
GORDONSVILLE
CHARLOTTESVILLE
DOSWELL
RICHMOND
WEST POINT
CHESTER
PETERSBURG
HOPEWELL
FORT LEE
WILLIAMSBURG
CAPE CHARLES
NORFOLK
SUFFOLK
EMPORIA
BOYKINS
FRANKLIN
CLARKSVILLE
DENNISTON
ROANOKE RAPIDS
WELDON
TUNIS
ELIZABETH CITY
KELFORD
EDENTON
ROCKY MOUNT
WILSON
SELMA
RALEIGH
DURHAM
GREENSBORO
WINSTON SALEM
OXFORD
PICKS SIDING
MOUNT AIRY
DANVILLE
MARTINSVILLE
ALTAVISTA
BROOKNEAL
ABILENE
MEHERRIN
BURKEVILLE
LYNCHBURG
BUCHANAN
BUENA VISTA
GLASGOW
BREMO
DILLWYN
ROANOKE
CLIFTON FORGE
WHITE SULPHUR SPRINGS
HINTON
CHARLESTON
COWEN
COALRUN
WILLIAMSON
IAEGER
MULLENS
BLUEFIELD
WALTON
RICHLANDS
NORA
BIG STONE GAP
HARLAN
SPEERS FERRY
BRISTOL
KINGSPORT
JOHNSON CITY
BULLS GAP
SALISBURY
SNOW HILL
POCOMOKE
NEW CHURCH
PARKSLEY
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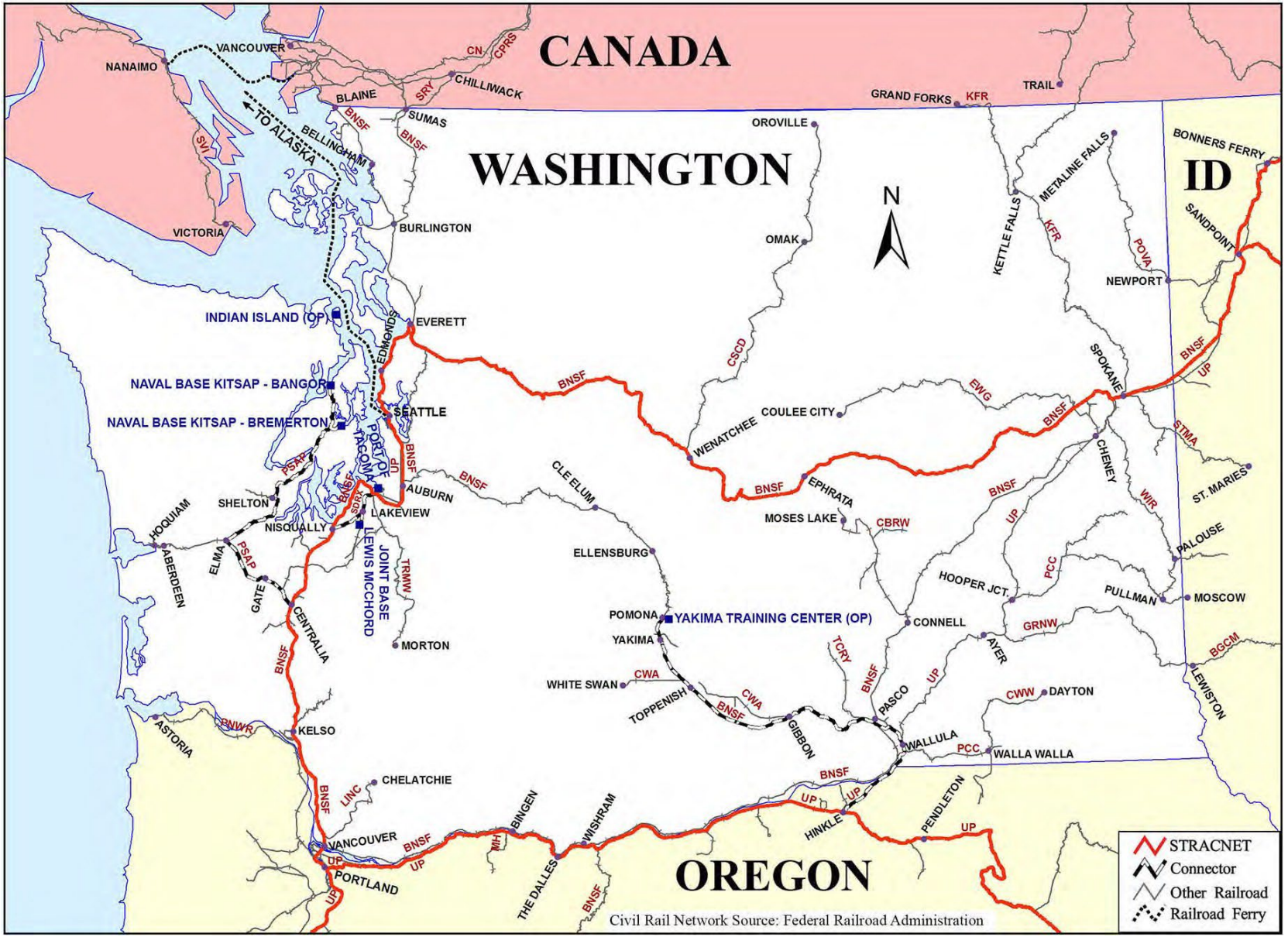
CANADA
WASHINGTON
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VICTORIA
BLAINE
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TO ALASKA
BELLINGHAM
BNSF
BURLINGTON
INDIAN ISLAND (OP)
EVERETT
EDMONDS
NAVAL BASE KITSAP - BANGOR
NAVAL BASE KITSAP - BREMERTON
SEATTLE
PORT OF TACOMA
UP
PSAP
SHELTON
HOQUIAM
ABERDEEN
ELMA
GATE
CENTRALIA
KELSO
ASTORIA
BNWR
SORX
NISQUALLY
LAKEVIEW
AUBURN
LEWIS MCCHORD
JOINT BASE
TRMW
MORTON
CLE ELUM
ELLENSBURG
POMONA
YAKIMA TRAINING CENTER (OP)
YAKIMA
WHITE SWAN
CWA
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GIBBON
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PORTLAND
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PENDLETON
OROVILLE
OMAK
GRAND FORKS
KFR
TRAIL
KETTLE FALLS
METALINE FALLS
BONNERS FERRY
SANDPOINT
NEWPORT
POVA
SPOKANE
CSCD
WENATCHEE
COULEE CITY
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EPHRATA
MOSES LAKE
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PALOUSE
PULLMAN
MOSCOW
HOOPER JCT.
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LEWISTON
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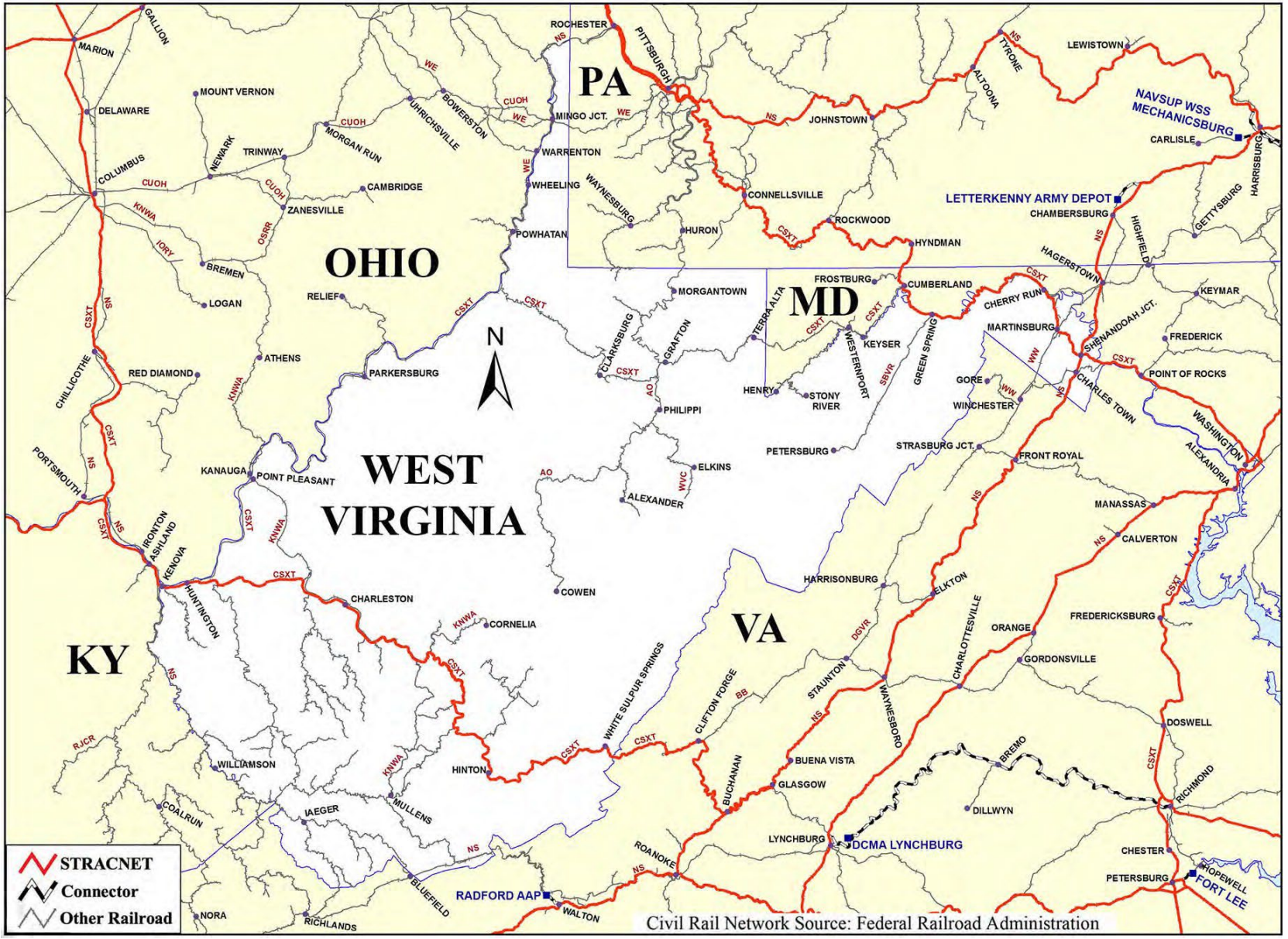
DAYTON
STRACNET
Connector
Other Railroad
Railroad Ferry
Civil Rail Network Source: Federal Railroad Administration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ALTOONA
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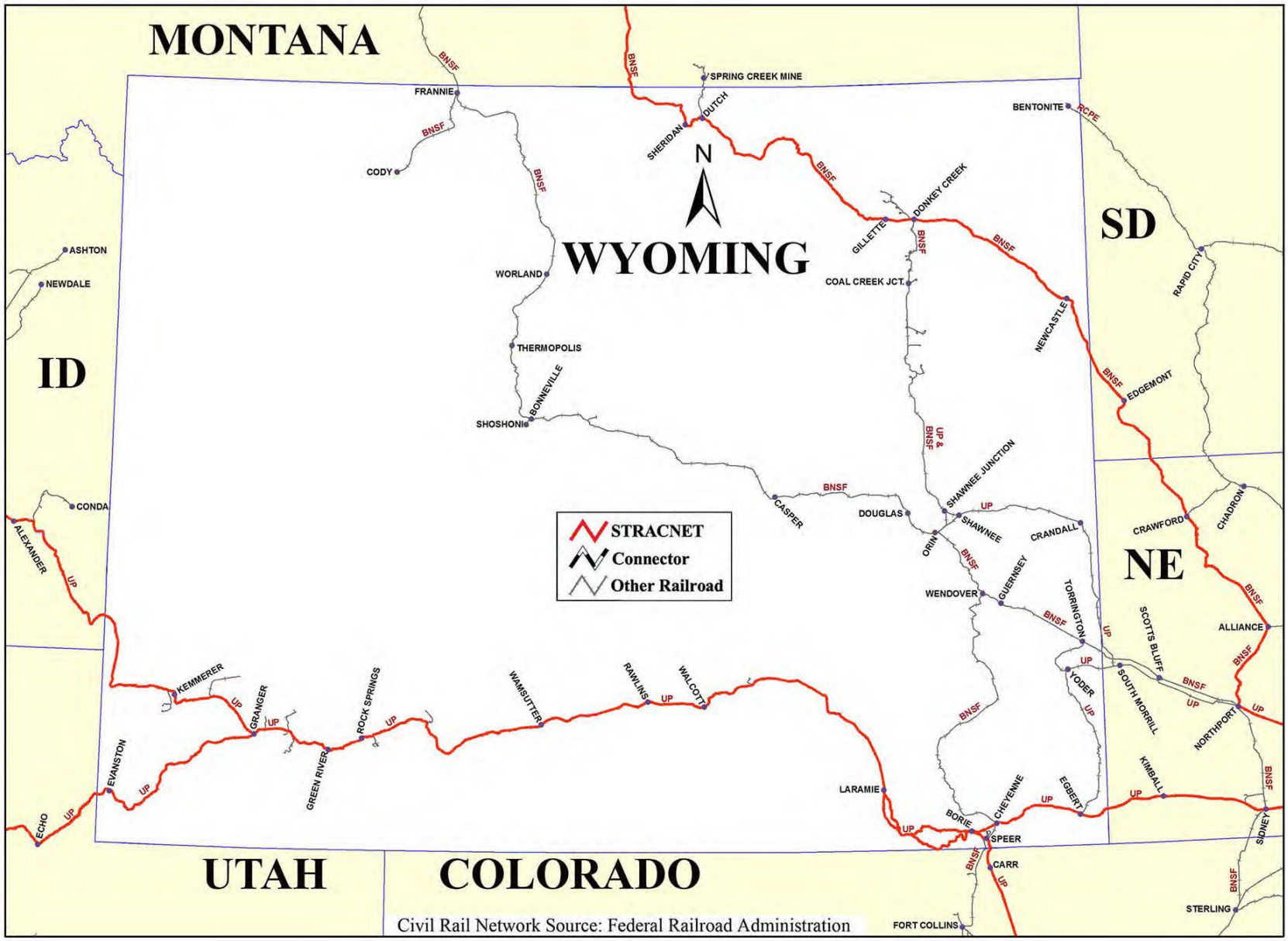
CONNELLSVILLE
ROCKWOOD
HYNDMAN
LETTERKENNY army DEPOT
CHAMBERSBURG
GETTYSBURG
HIGHFIELD
HAGERSTOWN
POWHATAN
HURON
MORGANTOWN
FROSTBURG
CUMBERLAND
CHERRY RUN
KEYMAR
MARTINSBURG
SHENANDOAH JCT.
FREDERICK
POINT OF ROCKS
CHARLES TOWN
WASHINGTON
ALEXANDRIA
MANASSAS
CALVERTON
FREDERICKSBURG
ORANGE
GORDONSVILLE
DOSWELL
RICHMOND
CHESTER
PETERSBURG
HOPEWELL
FORT LEE
DILLWYN
BREMO
BUENA VISTA
GLASGOW
LYNCHBURG
DCMA LYNCHBURG
ROANOKE
BLUEFIELD
RADFORD AAP
WALTON
RICHLANDS
NORA
COALRUN
IAEGER
MULLENS
WILLIAMSON
HINTON
CHARLESTON
CORNELIA
COWEN
HUNTINGTON
IRONTON
ASHLAND
KENOVA
PORTSMOUTH
KANAUGA
POINT PLEASANT
ATHENS
PARKERSBURG
RED DIAMOND
CHILLICOTHE
LOGAN
BREMEN
IORY
KNWA
OSRR
CUOH
WE
NS
CSXT
AO
WVC
SBVR
WW
DGVR
Bb
RJCR
BOWERSTON
UHRICHSVILLE
MORGAN RUN
NEWARK
TRINWAY
COLUMBUS
DELAWARE
MOUNT VERNON
MARION
GALLION
RELIEF
CLARKSBURG
GRAFTON
TERRA ALTA
PHILIPPI
ELKINS
ALEXANDER
HENRY
STONY RIVER
WESTERNPORT
KEYSER
GREEN SPRING
GORE
WINCHESTER
PETERSBURG
STRASBURG JCT.
FRONT ROYAL
HARRISONBURG
ELKTON
CHARLOTTESVILLE
STAUNTON
WAYNESBORO
CLIFTON FORGE
BUCHANAN
WHITE SULPHUR SPRINGS
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration

MI
WISCONSIN
MN
IOWA
IL
IN
N
STRACNET
Connector
Other Railroad
Civil Rail Network Source: Federal Railroad Administration
HIBBING
VIRGINIA
GUNN
BNSF
DULUTH
NSSR
TWO HARBORS
SUPERIOR
CN
CARLTON
BROOK PARK
HINCKLEY
NORTH BRANCH
SCXY
WGNS
STANBERRY
ASHLAND
MARENGO
WHITE PINE
BERGLAND
ROCKLAND
BARAGA
SIDNAW
ELS
NESTORIA
ISHPEMING
LSI
REPUBLIC
SAXON
CHANNING
IRON MOUNTAIN
POWERS
ESCANABA
CAMERON
LADYSMITH
PRENTICE
BRADLEY
TR
RHINELANDER
PEMBINE
CRIVITZ
MENOMINEE
MARINETTE
WAUSAU
ST. PAUL
MINNEAPOLIS
UP
CPRS
EAU CLAIRE
CHIPPEWA FALLS
SPENCER
GREEN BAY
RED WING
MERRILLAN
STEVENS POINT
MANAWA
ALMA
WISCONSIN RAPIDS
OWATONNA
ROCHESTER
FORT MCCOY
NECEDAH
NEENAH
OSHKOSH
MANITOWOC
WINONA
LA CRESCENT
LA CROSSE
TUNNEL CITY
PORTAGE
RIPON
WSOR
SHEBOYGAN
ALBERT LEA
AUSTIN
LYLE
REEDSBURG
MANLY
CHARLES CITY
CALMAR
PRAIRE DU CHIEN
MADISON
MILWAUKEE
MASON CITY
MARQUETTE
IOWA FALLS
WATERLOO
OELWEIN
JANESVILLE
MONROE
DUBUQUE
BELOIT
FOX LAKE
KENOSHA
MANCHESTER
PORTAGE
FREEPORT
ROCKFORD
WAUKEGAN
RONDOUT
MARSHALLTOWN
TAMA
IANR
CEDAR RAPIDS
SABULA
SAVANNA
TECHNY
CHICAGO
MICHIGAN CITY
UP
CLINTON
NELSON
DE KALB
AURORA
ROCHELLE
GARY
PORTER
NS
ROCK ISLAND ARSENAL
JOLIET


MONTANA
WYOMING
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NE
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UTAH
COLORADO
N
STRACNET
Connector
Other Railroad
SPRING CREEK MINE
FRANNIE
DUTCH
SHERIDAN
CODY
BENTONITE
DONKEY CREEK
GILLETTE
COAL CREEK JCT.
RAPID CITY
NEWCASTLE
EDGEMONT
ASHTON
NEWDALE
WORLAND
THERMOPOLIS
BONNEVILLE
SHOSHONI
CASPER
DOUGLAS
SHAWNEE JUNCTION
SHAWNEE
ORIN
CRANDALL
CRAWFORD
CHADRON
CONDA
ALEXANDER
WENDOVER
GUERNSEY
TORRINGTON
ALLIANCE
SCOTTS BLUFF
SOUTH MORRILL
YODER
NORTHPORT
KEMMERER
GRANGER
ROCK SPRINGS
GREEN RIVER
WAMSUTTER
RAWLINS
WALCOTT
EVANSTON
ECHO
LARAMIE
BORIE
CHEYENNE
EGBERT
KIMBALL
SIDNEY
SPEER
CARR
FORT COLLINS
STERLING
Civil Rail Network Source: Federal Railroad Administration

Appendix D: Economic Analysis Input Tables

Table 5: Beale AFB 2MW Generator Cost Input Model

ID #	Data Item	Materials	Labor	Equipment	*Source*
1	**Initial Scenario Planning Expenses**				
a	Microgrid	$ -	$ -	$ -	N/A
b	Staged Blackstart Strategy	$ -	$ -	$ -	N/A
c	Contracts Revision	$ -	$ 6,625	$ -	Estimation
d	Subtotal	$ -	$ 6,625	$ -	N/A
e	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
f	**Subtotal**	$ -	$ 8,659	$ -	N/A
g	**Total**		**$ 8,659**		N/A
2	**Physical System Upgrades**				
	Switchgear Building		-		N/A
a	Site Clearing and Grubbing	$ -	$ 730	$ 631	RSMeans 2021
b	Rough and Fine Grading	$ -	$ 912	$ 303	RSMeans 2021
c	Underground Electrical Line Installation	$ 56,875	$ 16,250	$ 8,125	IEEE Insulated Conductors Committee Meeting, Late 2019
d	Concrete Foundation	$ 8,720	$ 4,208	$ 1,744	RSMeans 2021
e	Solid Masonry Building	$ 45,920	$ 16,400	$ 3,280	Extrapolated from RSMeans 2019 data with R^2>.9998
f	Furnishing (lights, HVAC, fire supression, etc.)	$ 26,600	$ 7,600	$ 3,800	Industry Survey
g	Fence	$ 8,240	$ 366	$ 85	RSMeans 2021
	Electrical Components		-		N/A
h	2MW Generator	$ 1,272,000	$ 238,500	$ 79,500	EIA annual electric generator report ($795/kw)
i	35,000 Gallon Diesel Tank	$ 103,250	$ 2,217	$ -	RSMeans 2021
j	2MW Switchgear	$ 60,000	$ 13,333	$ 955	RSMeans 2019, Industry Survey
k	Protection, Switches, Metering, and Wiring	$ 119,355	$ 30,801	$ 3,850	RSMeans, NREL, Industry Survey
l	Electrical Controls	$ 30,000	$ 20,000	$ -	>10 years of team engineering experience
m	PII	$ 10,000	$ 180,000	$ 10,000	NREL 2018
n	Project Management	$ -	$ 93,750	$ -	Estimation
o	Subtotals	$ 1,740,960	$ 625,068	$ 112,273	N/A
p	General Requirements	$ 174,096	$ 62,507	$ 11,227	RSMeans 2021
q	Estimate Subtotal	$ 1,915,056	$ 687,574	$ 123,501	N/A
r	Sales Tax	$ 143,629	$ -	$ 9,263	RSMeans 2021
s	Subtotal A	$ 2,058,686	$ 687,574	$ 132,763	N/A
t	Overhead and Profit	$ 205,869	$ 68,757	$ 13,276	RSMeans 2021
u	Subtotal B	$ 2,264,554	$ 756,332	$ 146,040	N/A
v	Contingency	$ 169,842	$ 56,725	$ 10,953	RSMeans 2021
w	Subtotal C	$ 2,434,396	$ 813,057	$ 156,993	N/A
x	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
y	**Final Subtotal**	$ 2,478,215	$ 1,062,665	$ 205,189	N/A
z	**Total**		**$ 3,746,069**		N/A
3	**Preparation and Maintenance Costs**				
	Training		-		N/A
a	Yearly Electrical Training	$ -	$ 3,376	$ -	Salary from RSMeans
	Drills		-		N/A
b	Yearly Electrical Drill	$ -	$ 2,701	$ -	Salary from RSMeans
c	Additional Yearly Maintenance	$ 36,865	$ 23,459	$ 6,703	Common Rule of Thumb
d	Subtotal	$ 36,865	$ 29,536	$ 6,703	N/A
e	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
f	**Final Subtotal**	$ 37,528	$ 38,604	$ 8,760	N/A
g	**Total**		**$ 84,893**		N/A
4	**Scenario Operation Costs**				
	Personnel Costs				
a	Electrician Labor	$ -	$ 28,359	$ -	RSMeans 2021
b	Fuel Cost	$ 175,000	$ -	$ -	Market Survey
c	Subtotal	$ 175,000	$ 28,359	$ -	N/A
d	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
e	**Final Subtotal**	$ 178,150	$ 37,066	$ -	N/A
f	**Total**		**$ 215,216**		N/A

Table 6: Beale AFB Rail-to-Grid Cost Input Model

ID #	Data Item	Materials	Labor	Equipment	*Source*
1	**Initial Scenario Planning Expenses**				
a	Microgrid	$ -	$ -	$ -	N/A
b	Staged Blackstart Strategy	$ -	$ -	$ -	N/A
c	Contracts Revision	$ -	$ 579,688	$ -	Estimation
d	Rail-to-grid Payment Procedure Establishment	$ -	$ 2,518	$ -	Estimation
e	Subtotal	$ -	$ 582,205	$ -	N/A
f	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
g	**Subtotal**	$ -	$ 760,942	$ -	N/A
h	**Total**		**$ 760,942**		N/A
2	**Physical System Upgrades**				
	Switchgear Building		-		N/A
a	Site Clearing and Grubbing	$ -	$ 730	$ 631	RSMeans 2021
b	Rough and Fine Grading	$ -	$ 912	$ 303	RSMeans 2021
c	Underground Electrical Line Installation	$ 1,242,500	$ 355,000	$ 177,500	IEEE Insulated Conductors Committee meeting, Late 2019
d	Concrete Foundation	$ 8,720	$ 4,208	$ 1,744	RSMeans 2021
e	Solid Masonry Building	$ 45,920	$ 16,400	$ 3,280	Extrapolated from RSMeans 2019 data with R^2>.9998
f	Furnishing (lights, HVAC, fire supression, etc.)	$ 26,600	$ 7,600	$ 3,800	Industry Survey
g	Fence	$ 8,240	$ 366	$ 85	RSMeans 2021
	Electrical Components		-		N/A
h	2MW Inverter	$ 110,000	$ 9,045	$ 955	NREL- U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018
i	2000 kVA Transformer	$ 54,500	$ 6,350	$ 955	RSMeans 2021
j	Switchboard	$ 7,950	$ 1,950	$ -	RSMeans 2021
k	2MW Switchgear	$ 60,000	$ 13,333	$ 955	RSMeans 2019, Industry Survey
l	Protection, Switches, Metering, and Wiring	$ 119,355	$ 30,801	$ 3,850	RSMeans, NREL, Industry Survey
m	Electrical Controls	$ 30,000	$ 20,000	$ -	>10 years of team engineering experience
	Rail Components		-		N/A
n	Skid-mounted Diesel Fuel Pump	$ 22,000	$ -	$ -	Industry Survey
o	PII	$ 10,000	$ 180,000	$ 10,000	NREL 2018
p	Project Management	$ -	$ 93,750	$ -	Estimation
q	Subtotals	$ 1,745,785	$ 740,446	$ 204,058	N/A
r	General Requirements	$ 174,579	$ 74,045	$ 20,406	RSMeans 2021
s	Estimate Subtotal	$ 1,920,364	$ 814,491	$ 224,464	N/A
t	Sales Tax	$ 144,027	$ -	$ 16,835	RSMeans 2021
u	Subtotal A	$ 2,064,391	$ 814,491	$ 241,299	N/A
v	Overhead and Profit	$ 206,439	$ 81,449	$ 24,130	RSMeans 2021
w	Subtotal B	$ 2,270,830	$ 895,940	$ 265,429	N/A
x	Contingency	$ 170,312	$ 67,195	$ 19,907	RSMeans 2021
y	Subtotal C	$ 2,441,143	$ 963,135	$ 285,336	N/A
z	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
aa	**Final Subtotal**	$ 2,485,083	$ 1,258,818	$ 372,934	N/A
ab	**Total**		**$ 4,116,835**		N/A
3	**Preparation and Maintenance Costs**				
	Training		-		N/A
a	Yearly Electrical Training	$ -	$ 3,376	$ -	Salary from RSMeans
b	Yearly Rail Training	$ -	$ 95,162	$ -	Salary from RSMeans
	Drills		-		N/A
c	Yearly Installation Drill	$ -	$ 375,000	$ -	https://www.airforcemag.com/dods-black-start-exercises-explore-what-happens-when-utilities-go-dark/
d	Yearly Electrical Drill	$ -	$ 2,701	$ -	Salary from RSMeans
e	Yearly Rail Drill	$ -	$ 4,905	$ -	Salary from RSMeans
f	Additional Yearly Maintenance	$ 36,967	$ 23,524	$ 6,721	Common Rule of Thumb
g	Subtotal	$ 36,967	$ 504,668	$ 6,721	N/A
h	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
i	**Final Subtotal**	$ 37,632	$ 659,602	$ 8,785	N/A
j	**Total**		**$ 706,019**		N/A
4	**Scenario Operation Costs**				
	Personnel Costs				
a	AMC Management Labor	$ -	$ 2,650	$ -	Estimation
b	Rail Crew Labor	$ -	$ 52,203	$ -	RSMeans 2021
c	Rail Crew TDY Cost	$ -	$ 17,172	$ -	2022 Government Pay Tables
d	HAZMAT Escort Labor	$ -	$ 2,719	$ -	RSMeans 2021- Assumed same as rail crew
e	HAZMAT Escort TDY Cost	$ -	$ 3,312	$ -	2022 Government Pay Tables
f	Electrician Labor	$ -	$ 28,359	$ -	RSMeans 2021
g	Rail Use Costs	$ -	$ -	$ 66,192	Congressional Budget Office's 2015 *Pricing Freight Transport To Account for External Costs*
h	Fuel Cost	$ 176,352	$ -	$ -	Market Survey
i	Subtotal	$ 176,352	$ 106,415	$ 66,192	N/A
j	Location Cost Factor	1.018	1.307	1.307	RSMeans 2021
k	**Final Subtotal**	$ 179,526	$ 139,084	$ 86,513	N/A
l	**Total**		**$ 405,124**		N/A

Table 7: Fort Lee 2MW Generator Cost Input Model

ID #	Data Item	Materials	Labor	Equipment	*Source*
1	**Initial Scenario Planning Expenses**				
a	Microgrid	$ -	$ -	$ -	N/A
b	Staged Blackstart Strategy	$ -	$ -	$ -	N/A
c	Contracts Revision	$ -	$ 6,625	$ -	Estimation
d	Subtotal	$ -	$ 6,625	$ -	N/A
e	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
f	**Subtotal**	$ -	$ 4,929	$ -	N/A
g	**Total**		**$ 4,929**		N/A
2	**Physical System Upgrades**				
	Switchgear Building		-		N/A
a	Site Clearing and Grubbing	$ -	$ 730	$ 631	RSMeans 2021
b	Rough and Fine Grading	$ -	$ 912	$ 303	RSMeans 2021
c	Underground Electrical Line Installation	$ 19,110	$ 5,460	$ 2,730	IEEE Insulated Conductors Committee meeting in late 2019
d	Concrete Foundation	$ 8,720	$ 4,208	$ 1,744	RSMeans 2021
e	Solid Masonry Building	$ 45,920	$ 16,400	$ 3,280	Extrapolated from RSMeans 2019 data with R^2>.9998
f	Furnishing (lights, HVAC, fire supression, etc.)	$ 26,600	$ 7,600	$ 3,800	Industry Survey
g	Fence	$ 8,240	$ 366	$ 85	RSMeans 2021
	Electrical Components		-		N/A
h	2MW Generator	$ 1,272,000	$ 238,500	$ 79,500	EIA annual electric generator report ($795/kw)
i	35,000 Gallon Diesel Tank	$ 103,250	$ 2,217	$ -	RSMeans 2021
j	2MW Switchgear	$ 60,000	$ 13,333	$ 955	RSMeans 2019, Industry Survey
k	Protection, Switches, Metering, and Wiring	$ 119,355	$ 30,801	$ 3,850	RSMeans, NREL, Industry Survey
l	Electrical Controls	$ 30,000	$ 20,000	$ -	>10 years of team engineering experience
m	PII	$ 10,000	$ 180,000	$ 10,000	NREL 2018
n	Project Management	$ -	$ 93,750	$ -	Estimation
o	Subtotals	$ 1,703,195	$ 614,278	$ 106,878	N/A
p	General Requirements	$ 170,320	$ 61,428	$ 10,688	RSMeans 2021
q	Estimate Subtotal	$ 1,873,515	$ 675,705	$ 117,566	N/A
r	Sales Tax	$ 112,922	$ -	$ 7,086	RSMeans 2021
s	Subtotal A	$ 1,986,437	$ 675,705	$ 124,652	N/A
t	Overhead and Profit	$ 198,644	$ 67,571	$ 12,465	RSMeans 2021
u	Subtotal B	$ 2,185,081	$ 743,276	$ 137,117	N/A
v	Contingency	$ 163,881	$ 55,746	$ 10,284	RSMeans 2021
w	Subtotal C	$ 2,348,962	$ 799,022	$ 147,401	N/A
x	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
y	**Final Subtotal**	$ 2,334,868	$ 594,472	$ 109,667	N/A
z	**Total**		**$ 3,039,006**		N/A
3	**Preparation and Maintenance Costs**				
	Training		-		N/A
a	Yearly Electrical Training	$ -	$ 3,376	$ -	RSMeans 2021
	Drills		-		N/A
b	Yearly Electrical Drill	$ -	$ 2,701	$ -	Salary from RSMeans
c	Additional Yearly Maintenance	$ 36,065	$ 22,951	$ 6,557	Common Rule of Thumb
d	Subtotal	$ 36,065	$ 29,028	$ 6,557	N/A
e	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
f	**Final Subtotal**	$ 35,849	$ 21,596	$ 4,879	N/A
g	**Total**		**$ 62,324**		N/A
4	**Scenario Operation Costs**				
	Personnel Costs				
a	Electrician Labor	$ -	$ 28,359	$ -	RSMeans 2021
b	Fuel Cost	$ 175,000	$ -	$ -	Market Survey
c	Subtotal	$ 175,000	$ 28,359	$ -	N/A
d	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
e	**Final Subtotal**	$ 173,950	$ 21,099	$ -	N/A
f	**Total**		**$ 195,049**		N/A

Table 8: Fort Lee Rail-to-Grid Cost Input Model

ID #	Data Item	Materials	Labor	Equipment	*Source*
1	**Initial Scenario Planning Expenses**				
a	Microgrid	$ -	$ -	$ -	N/A
b	Staged Blackstart Strategy	$ -	$ -	$ -	N/A
c	Contracts Revision	$ -	$ 579,688	$ -	Estimation
d	Rail-to-grid Payment Procedure Establishment	$ -	$ 2,518	$ -	Estimation
e	Subtotal	$ -	$ 582,205	$ -	N/A
f	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
g	**Subtotal**	$ -	$ 433,161	$ -	N/A
h	**Total**		**$ 433,161**		N/A
2	**Physical System Upgrades**				
	Switchgear Building		-		N/A
a	Site Clearing and Grubbing	$ -	$ 730	$ 631	RSMeans 2021
b	Rough and Fine Grading	$ -	$ 912	$ 303	RSMeans 2021
c	Underground Electrical Line Installation	$ 261,660	$ 74,760	$ 37,380	IEEE Insulated Conductors Committee meeting, Late 2019
d	Concrete Foundation	$ 8,720	$ 4,208	$ 1,744	RSMeans 2021
e	Solid Masonry Building	$ 45,920	$ 16,400	$ 3,280	Extrapolated from RSMeans 2019 data with R^2>.9998
f	Furnishing (lights, HVAC, fire supression, etc.)	$ 26,600	$ 7,600	$ 3,800	Industry Survey
g	Fence	$ 8,240	$ 366	$ 85	RSMeans 2021
	Electrical Components		-		N/A
h	2MW Inverter	$ 110,000	$ 9,045	$ 955	NREL- U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018
i	2000 kVA Transformer	$ 54,500	$ 6,350	$ 955	RSMeans 2021
j	Switchboard	$ 7,950	$ 1,950	$ -	RSMeans 2021
k	2MW Switchgear	$ 60,000	$ 13,333	$ 955	RSMeans 2019, Industry Survey
l	Protection, Switches, Metering, and Wiring	$ 119,355	$ 30,801	$ 3,850	RSMeans, NREL, Industry Survey
m	Electrical Controls	$ 30,000	$ 20,000	$ -	>10 years of team engineering experience
	Rail Components		-		N/A
n	Skid-mounted Diesel Fuel Pump	$ 22,000	$ -	$ -	Industry Survey
o	PII	$ 10,000	$ 180,000	$ 10,000	NREL 2018
p	Project Management	$ -	$ 93,750	$ -	Estimation
q	Subtotals	$ 764,945	$ 460,206	$ 63,938	N/A
r	General Requirements	$ 76,495	$ 46,021	$ 6,394	RSMeans 2021
s	Estimate Subtotal	$ 841,440	$ 506,227	$ 70,332	N/A
t	Sales Tax	$ 50,716	$ -	$ 4,239	RSMeans 2021
u	Subtotal A	$ 892,156	$ 506,227	$ 74,571	N/A
v	Overhead and Profit	$ 89,216	$ 50,623	$ 7,457	RSMeans 2021
w	Subtotal B	$ 981,371	$ 556,849	$ 82,028	N/A
x	Contingency	$ 73,603	$ 41,764	$ 6,152	RSMeans 2021
y	Subtotal C	$1,054,974	$ 598,613	$ 88,181	N/A
z	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
aa	**Final Subtotal**	$1,048,644	$ 445,368	$ 65,606	N/A
ab	**Total**		**$ 1,559,619**		N/A
3	**Preparation and Maintenance Costs**				
	Training		-		N/A
a	Yearly Electrical Training	$ -	$ 3,376	$ -	Salary from RSMeans
b	Yearly Rail Training	$ -	$ 95,162	$ -	Salary from RSMeans
	Drills		-		N/A
c	Yearly Installation Drill	$ -	$ 375,000	$ -	https://www.airforcemag.com/dods-black-start-exercises-explore-what-happens-when-utilities-go-dark/
d	Yearly Electrical Drill	$ -	$ 2,701	$ -	Salary from RSMeans
e	Yearly Rail Drill	$ -	$ 4,905	$ -	Salary from RSMeans
f	Additional Yearly Maintenance	$ 16,198	$ 10,308	$ 2,945	Common Rule of Thumb
g	Subtotal	$ 16,198	$ 491,452	$ 2,945	N/A
h	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
i	**Final Subtotal**	$ 16,101	$ 365,640	$ 2,191	N/A
j	**Total**		**$ 383,932**		N/A
4	**Scenario Operation Costs**				
	Personnel Costs				N/A
a	AMC Management Labor	$ -	$ 2,650	$ -	Estimation
b	Rail Crew Labor	$ -	$ 52,203	$ -	RSMeans 2021
c	Rail Crew TDY Cost	$ -	$ 17,172	$ -	2022 Government Pay Tables
d	HAZMAT Escort Labor	$ -	$ 2,719	$ -	RSMeans 2021- Assumed same as rail crew
e	HAZMAT Escort TDY Cost	$ -	$ 3,312	$ -	2022 Government Pay Tables
f	Electrician Labor	$ -	$ 28,359	$ -	RSMeans 2021
g	Rail Use Costs	$ -	$ -	$ 66,192	Congressional Budget Office's 2015 *Pricing Freight Transport To Account for External Costs*
h	Fuel Cost	$ 176,352	$ -	$ -	Market Survey
i	Subtotal	$ 176,352	$ 106,415	$ 66,192	N/A
j	Location Cost Factor	0.994	0.744	0.744	RSMeans 2021
k	**Final Subtotal**	$ 175,294	$ 79,173	$ 49,247	N/A
l	**Total**		**$ 303,714**		N/A

Table 9: Camp Shelby 2MW Generator Cost Input Model

ID #	Data Item	Materials	Labor	Equipment	*Source*
1	**Initial Scenario Planning Expenses**				
a	Microgrid	$ -	$ -	$ -	N/A
b	Staged Blackstart Strategy	$ -	$ -	$ -	N/A
c	Contracts Revision	$ -	$ 6,625	$ -	Estimation
d	Subtotal	$ -	$ 6,625	$ -	N/A
e	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
f	**Subtotal**	$ -	$ 3,737	$ -	N/A
g	**Total**		**$ 3,737**		N/A
2	**Physical System Upgrades**				
	Switchgear Building		-		N/A
a	Site Clearing and Grubbing	$ -	$ 730	$ 631	RSMeans 2021
b	Rough and Fine Grading	$ -	$ 912	$ 303	RSMeans 2021
c	Underground Electrical Line Installation	$ 9,100	$ 2,600	$ 1,300	IEEE Insulated Conductors Committee meeting in late 2019
d	Concrete Foundation	$ 8,720	$ 4,208	$ 1,744	RSMeans 2021
e	Solid Masonry Building	$ 45,920	$ 16,400	$ 3,280	Extrapolated from RSMeans 2019 data with R^2>.9998
f	Furnishing (lights, HVAC, fire supression, etc.)	$ 26,600	$ 7,600	$ 3,800	Industry Survey
g	Fence	$ 8,240	$ 366	$ 85	RSMeans 2021
	Electrical Components		-		N/A
h	2MW Generator	$ 1,272,000	$ 238,500	$ 79,500	EIA annual electric generator report ($795/kw)
i	35,000 Gallon Diesel Tank	$ 103,250	$ 2,217	$ -	RSMeans 2021
j	2MW Switchgear	$ 60,000	$ 13,333	$ 955	RSMeans 2019, Industry Survey
k	Protection, Switches, Metering, and Wiring	$ 119,355	$ 30,801	$ 3,850	RSMeans, NREL, Industry Survey
l	Electrical Controls	$ 30,000	$ 20,000	$ -	>10 years of team engineering experience
m	PII	$ 10,000	$ 180,000	$ 10,000	NREL 2018
n	Project Management	$ -	$ 93,750	$ -	Estimation
o	Subtotals	$ 1,693,185	$ 611,418	$ 105,448	N/A
p	General Requirements	$ 169,319	$ 61,142	$ 10,545	RSMeans 2021
q	Estimate Subtotal	$ 1,862,504	$ 672,559	$ 115,993	N/A
r	Sales Tax	$ 118,523	$ -	$ 7,381	RSMeans 2021
s	Subtotal A	$ 1,981,027	$ 672,559	$ 123,375	N/A
t	Overhead and Profit	$ 198,103	$ 67,256	$ 12,337	RSMeans 2021
u	Subtotal B	$ 2,179,130	$ 739,815	$ 135,712	N/A
v	Contingency	$ 163,435	$ 55,486	$ 10,178	RSMeans 2021
w	Subtotal C	$ 2,342,564	$ 795,302	$ 145,890	N/A
x	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
y	**Final Subtotal**	$ 2,267,602	$ 448,550	$ 82,282	N/A
z	**Total**		**$ 2,798,435**		N/A
3	**Preparation and Maintenance Costs**				
	Training		-		N/A
a	Yearly Electrical Training	$ -	$ 3,376	$ -	Salary from RSMeans
	Drills		-		N/A
b	Yearly Electrical Drill	$ -	$ 2,701	$ -	Salary from RSMeans
c	Additional Yearly Maintenance	$ 35,853	$ 22,816	$ 6,519	Common Rule of Thumb
d	Subtotal	$ 35,853	$ 28,893	$ 6,519	N/A
e	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
f	**Final Subtotal**	$ 34,706	$ 16,295	$ 3,677	N/A
g	**Total**		**$ 54,678**		N/A
4	**Scenario Operation Costs**				
	Personnel Costs				N/A
a	Electrician Labor	$ -	$ 28,359	$ -	RSMeans 2021
b	Fuel Cost	$ 175,000	$ -	$ -	Market Survey
c	Subtotal	$ 175,000	$ 28,359	$ -	N/A
d	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
e	**Final Subtotal**	$ 169,400	$ 15,995	$ -	N/A
f	**Total**		**$ 185,395**		N/A

Table 10: Camp Shelby Rail-to-Grid Cost Input Model

ID #	Data Item	Materials	Labor	Equipment	*Source*
1	**Initial Scenario Planning Expenses**				
a	Microgrid	$ -	$ -	$ -	N/A
b	Staged Blackstart Strategy	$ -	$ -	$ -	N/A
c	Contracts Revision	$ -	$ 579,688	$ -	Estimation
d	Rail-to-grid Payment Procedure Establishment	$ -	$ 2,518	$ -	Estimation
e	Subtotal	$ -	$ 582,205	$ -	N/A
f	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
g	**Subtotal**	$ -	$ 328,364	$ -	N/A
h	**Total**		**$ 328,364**		N/A
2	**Physical System Upgrades**				
	Switchgear Building		-		N/A
a	Site Clearing and Grubbing	$ -	$ 730	$ 631	RSMeans 2021
b	Rough and Fine Grading	$ -	$ 912	$ 303	RSMeans 2021
c	Underground Electrical Line Installation	$ 124,600	$ 35,600	$ 17,800	IEEE Insulated Conductors Committee meeting in late 2019
d	Concrete Foundation	$ 8,720	$ 4,208	$ 1,744	RSMeans 2021
e	Solid Masonry Building	$ 45,920	$ 16,400	$ 3,280	Extrapolated from RSMeans 2019 data with R^2>.9998
f	Furnishing (lights, HVAC, fire supression, etc.)	$ 26,600	$ 7,600	$ 3,800	Industry Survey
g	Fence	$ 8,240	$ 366	$ 85	RSMeans 2021
	Electrical Components		-		N/A
h	2MW Inverter	$ 110,000	$ 9,045	$ 955	NREL- U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018
i	2000 kVA Transformer	$ 54,500	$ 6,350	$ 955	RSMeans 2021
j	Switchboard	$ 7,950	$ 1,950	$ -	RSMeans 2021
k	2MW Switchgear	$ 60,000	$ 13,333	$ 955	RSMeans 2019, Industry Survey
l	Protection, Switches, Metering, and Wiring	$ 119,355	$ 30,801	$ 3,850	RSMeans, NREL, Industry Survey
m	Electrical Controls	$ 30,000	$ 20,000	$ -	>10 years of team engineering experience
	Rail Components		-		N/A
n	Skid-mounted Diesel Fuel Pump	$ 22,000	$ -	$ -	Industry Survey
o	330 Feet of Track	$ 60,584	$ 13,981	$ 18,641	Industry Survey
p	PII	$ 10,000	$ 180,000	$ 10,000	NREL 2018
q	Project Management	$ -	$ 93,750	$ -	Estimation
r	Subtotals	$ 688,469	$ 435,027	$ 62,999	N/A
s	General Requirements	$ 68,847	$ 43,503	$ 6,300	RSMeans 2021
t	Estimate Subtotal	$ 757,316	$ 478,530	$ 69,299	N/A
u	Sales Tax	$ 48,193	$ -	$ 4,410	RSMeans 2021
v	Subtotal A	$ 805,509	$ 478,530	$ 73,709	N/A
w	Overhead and Profit	$ 80,551	$ 47,853	$ 7,371	RSMeans 2021
x	Subtotal B	$ 886,060	$ 526,383	$ 81,080	N/A
y	Contingency	$ 66,454	$ 39,479	$ 6,081	RSMeans 2021
z	Subtotal C	$ 952,514	$ 565,861	$ 87,161	N/A
aa	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
ab	**Final Subtotal**	$ 922,034	$ 319,146	$ 49,159	N/A
ac	**Total**		**$ 1,290,338**		N/A
3	**Preparation and Maintenance Costs**				
	Training		-		N/A
a	Yearly Electrical Training	$ -	$ 3,376	$ -	Salary from RSMeans
b	Yearly Rail Training	$ -	$ 95,162	$ -	Salary from RSMeans
	Drills		-		N/A
c	Yearly Installation Drill	$ -	$ 375,000	$ -	https://www.airforcemag.com/dods-black-start-exercises-explore-what-happens-when-utilities-go-dark/
d	Yearly Electrical Drill	$ -	$ 2,701	$ -	Salary from RSMeans
e	Yearly Rail Drill	$ -	$ 4,905	$ -	Salary from RSMeans
f	Additional Yearly Maintenance	$ 14,578	$ 9,277	$ 2,651	Common Rule of Thumb
g	Subtotal	$ 14,578	$ 490,421	$ 2,651	N/A
h	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
i	**Final Subtotal**	$ 14,112	$ 276,597	$ 1,495	N/A
j	**Total**		**$ 292,204**		N/A
4	**Scenario Operation Costs**				
	Personnel Costs				N/A
a	AMC Management Labor	$ -	$ 2,650	$ -	Estimation
b	Rail Crew Labor	$ -	$ 52,203	$ -	RSMeans 2021
c	Rail Crew TDY Cost	$ -	$ 17,172	$ -	2022 Government Pay Tables
d	HAZMAT Escort Labor	$ -	$ 2,719	$ -	RSMeans 2021- Assumed same as rail crew
e	HAZMAT Escort TDY Cost	$ -	$ 3,312	$ -	2022 Government Pay Tables
f	Electrician Labor	$ -	$ 28,359	$ -	RSMeans 2021
g	Rail Use Costs	$ -	$ -	$ 66,192	Congressional Budget Office's 2015 *Pricing Freight Transport To Account for External Costs*
h	Fuel Cost	$ 176,352	$ -	$ -	Market Survey
i	Subtotal	$ 176,352	$ 106,415	$ 66,192	N/A
j	Location Cost Factor	0.968	0.564	0.564	RSMeans 2021
k	**Final Subtotal**	$ 170,709	$ 60,018	$ 37,333	N/A
l	**Total**		**$ 268,059**		N/A

Appendix E: Economic Analysis Outputs

NIST BLCC 5.3-21: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Beale AFB RTG

Alternative: Beale AFB 2 MWG

General Information

File Name:	C:\Users\u4cfemaa\Desktop\Beala AFB RTG.xml
Date of Study:	Wed Sep 28 15:07:13 CDT 2022
Project Name:	
Project Location:	California
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	
Base Date:	September 1, 2022
Service Date:	September 1, 2022
Study Period:	10 years 0 months(September 1, 2022 through August 31, 2032)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$760,942	$8,659	$752,283
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$15,101,874	$6,747,157	$8,354,717
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$15,101,874	$6,747,157	$8,354,717
Total PV Life-Cycle Cost	$15,862,816	$6,755,816	$9,107,000

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$8,354,717
- Increased Total Investment	-$752,283
Net Savings	$9,107,000

NOTE: Meaningful SIR, AIRR and Payback can not be computed unless incremental savings and total savings are both positive.

NIST BLCC 5.3-21: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Beale AFB RTG

Alternative: Beale AFB 2 MWG

General Information

File Name:	C:\Users\u4cfemaa\Desktop\BealaAFBRTG.xml
Date of Study:	Tue Sep 27 15:22:08 CDT 2022
Project Name:	
Project Location:	California
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	
Base Date:	September 1, 2022
Service Date:	September 1, 2022
Study Period:	30 years 0 months(September 1, 2022 through August 31, 2052)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$760,942	$8,659	$752,283
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$36,295,169	$12,749,337	$23,545,832
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$36,295,169	$12,749,337	$23,545,832
Total PV Life-Cycle Cost	$37,056,111	$12,757,996	$24,298,115

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$23,545,832
- Increased Total Investment	-$752,283

NIST BLCC 5.3-21: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Fort Lee RTG

Alternative: Fort Lee 2 MWG

General Information

File Name:	C:\Users\u4cfemaa\Desktop\FtLee.xml
Date of Study:	Wed Sep 28 15:13:04 CDT 2022
Project Name:	
Project Location:	Virginia
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	
Base Date:	September 1, 2022
Service Date:	September 1, 2022
Study Period:	10 years 0 months(September 1, 2022 through August 31, 2032)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$433,161	$4,929	$428,232
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$8,430,716	$5,612,736	$2,817,980
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$8,430,716	$5,612,736	$2,817,980
Total PV Life-Cycle Cost	$8,863,877	$5,617,665	$3,246,212

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$2,817,980
- Increased Total Investment	-$428,232

NIST BLCC 5.3-21: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Fort Lee RTG

Alternative: Fort Lee 2 MWG

General Information

File Name:	C:\Users\u4cfemaa\Desktop\FtLee.xml
Date of Study:	Wed Sep 28 14:54:43 CDT 2022
Project Name:	
Project Location:	Virginia
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	
Base Date:	September 1, 2022
Service Date:	September 1, 2022
Study Period:	30 years 0 months(September 1, 2022 through August 31, 2052)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$433,161	$4,929	$428,232
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$22,151,045	$10,760,196	$11,390,849
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$22,151,045	$10,760,196	$11,390,849
Total PV Life-Cycle Cost	$22,584,206	$10,765,125	$11,819,081

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$11,390,849
- Increased Total Investment	-$428,232

NIST BLCC 5.3-21: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Camp Shelby RTG

Alternative: Camp Shelby 2 MWG

General Information

File Name:	C:\Users\u4cfemaa\Desktop\CampShelby.xml
Date of Study:	Tue Sep 27 15:55:04 CDT 2022
Project Name:	
Project Location:	California
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	
Base Date:	September 1, 2022
Service Date:	September 1, 2022
Study Period:	10 years 0 months(September 1, 2022 through August 31, 2032)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$328,364	$3,737	$324,627
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$6,839,031	$5,199,164	$1,639,867
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$6,839,031	$5,199,164	$1,639,867
Total PV Life-Cycle Cost	$7,167,395	$5,202,901	$1,964,494

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$1,639,867
- Increased Total Investment	-$324,627
	$1,315,240

NIST BLCC 5.3-21: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Camp Shelby RTG

Alternative: Camp Shelby 2 MWG

General Information

File Name:	C:\Users\u4cfemaa\Desktop\CampShelby.xml
Date of Study:	Tue Sep 27 15:59:58 CDT 2022
Project Name:	
Project Location:	Mississippi
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	
Base Date:	September 1, 2022
Service Date:	September 1, 2022
Study Period:	30 years 0 months(September 1, 2022 through August 31, 2052)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$328,364	$3,737	$324,627
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$17,712,764	$10,000,624	$7,712,140
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$17,712,764	$10,000,624	$7,712,140
Total PV Life-Cycle Cost	$18,041,128	$10,004,361	$8,036,767

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$7,712,140
- Increased Total Investment	-$324,627