US Army Corps of Engineers

Addendum 1 of Appendix D, Economics – Attachment 2: Lock Capacity Calibration Report

Inner Harbor Navigation Canal (IHNC) Lock – Lock Replacement, Orleans Parish, Louisiana

General Reevaluation Report

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Table of Contents

Table of Figures

Attachment 2 - ARNOLT Calibration Report: IHNC Lock

1. Introduction

A key component of any assessment of lock benefits is that lock's capacity, which in very broad terms refers to the amount of traffic the project can accommodate. It is not only the upper limit of traffic that can process through the project that is of importance. However, in many cases few if any analyzed scenarios or project conditions will involve traffic levels at or near that threshold. What is typically a more significant factor is how the efficiency of the project responds to increases or decreases in traffic volumes.

The ARNOLT (Analysis of River Navigation and Operational Lock Throughput) model, developed by the PCXIN, is used to assess a lock's capacity, represented as the average transit time for users of the lock as a function of its annual tonnage throughput. This is commonly referred to as a "tonnage transit curve," where the average transit time, on the y axis, is displayed as a function of the annual tonnage on the x axis.

The ARNOLT model performs a stochastic simulation of lock operation over a year period, from which it can assess capacity. This simulation is fed by data from the Lock Performance Monitoring System (LPMS) which supplies data on historic lock usage patterns and levels as well as processing times, the Waterborne Commerce Statistics Center (WCSC) which supplies data on tonnage volumes by commodity, and user input data which among many others specifies operating policies, simulation settings, and how other input data will be used.

Because ARNOLT is essentially a simulation of lock operation (used to generate capacity estimates), and because the simulation is complex and involves many uncertain variables, a thorough calibration process is necessary to ensure the model is set up to accurately reflect the reality it's attempting to simulate. This entails ensuring that all input datasets (LPMS and WCSC) are valid and free of substantial data errors, that all user specified input parameters are valid and reflect on the ground reality, and most importantly (and as result of the first two) that the model is able to accurately reproduce historical outcomes. This document will describe this calibration process.

2. ARNOLT Inputs

The Inner Harbor Navigation Canal (IHNC) operates with a single 640' x 75' chamber. This chamber processes an approximate 15M tons every year and is among the most highly congested lock projects in the nation. In addition to the strain placed on a comparatively small chamber by a large volume of traffic, the project also closes frequently, twice each weekday, to accommodate traffic over the three vertical lift bridges that effectively connect the Lower Ninth Ward to the rest of the city.

2.1. LPMS Data

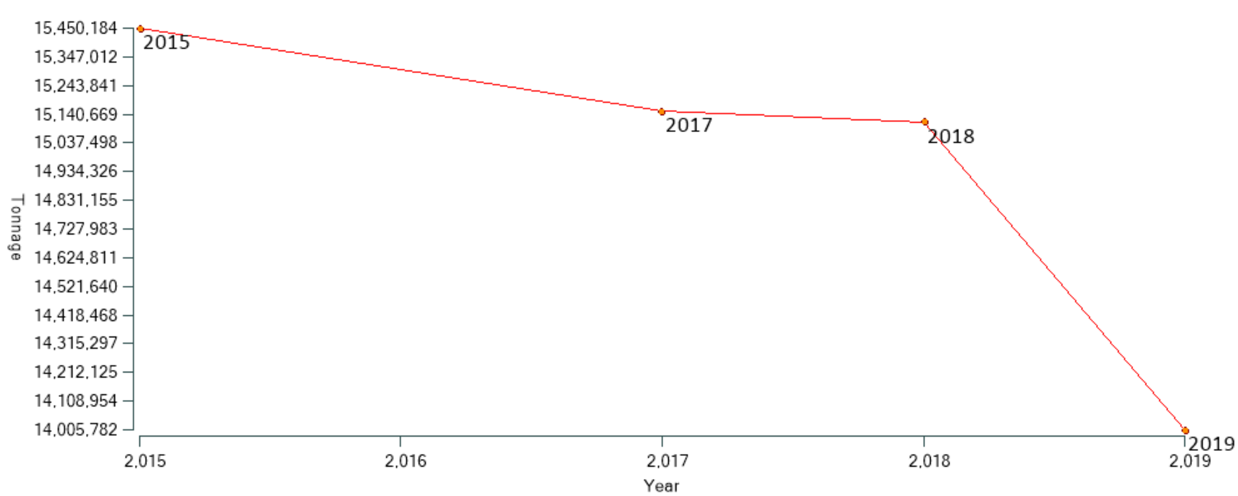
The primary data source used in characterizing a lock and its traffic is the Lock Performance Monitoring System (LPMS). The relevant years of LPMS data, as well as any alterations made to these data, are of great importance to the calibration of the model. For this analysis, data years

2015, 2017, 2018, and 2019 were used. Other years were excluded due to either prolonged closures which could bias the arrival distributions and traffic composition, or due to economic downturn resulting from the Covid-19 pandemic. As traffic patterns likely shifted during these years, they would not be representative of baseline traffic. Closures of the duration that occurred in excluded years (any closure not considered "random minor") would be separately simulated in ARNOLT.

In the LPMS data years used, substantial corrections were necessary due to non-traditional recording of data at the IHNC project. Because of the location of the project, flotillas which need multiple cuts to transit will break and remake tows outside of the canal, approximately 1.5 miles North or 0.5 miles South of the lock. This means that when they arrive at the project and are correspondingly recorded in LPMS as an arrival, they are pre-configured flotilla elements that can transit in a single cut, no longer necessarily being pushed by the powered vessel with which they arrived. They are then recorded in LPMS as a separate flotilla. (The unique identifier in the LPMS database for a Flotilla is a primary key consisting of Flotilla ID, Vessel ID, and EROC, so transits recorded with different Vessel ID's will be recorded as disaggregated flotillas). This issue carries over to other elements of data recording in LPMS, including arrival times (each cut recorded as a separate arrival), lockage types (each transit recorded as a single-cut straight lockage), etc. To correct this issue, each LPMS dataset used had to be manually edited to re-aggregate flotillas into the configuration they were in during transit to the project.

The ARNOLT simulation for IHNC used a combination of years 2017 and 2018 for its base year. When multiple LPMS years are selected as the base year, the average traffic volume between these years is used. LPMS tonnage across used LPMS data years is shown below.

Figure 1 - Project Tonnage over LPMS Years

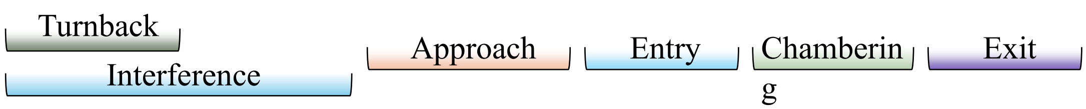


3. Lockage Timing

As flotillas of various sizes, configurations, and numbers of barges attempt to navigate a lock, they will process through in different ways. Some will be able to transit in a single cut, while others will require multiple cuts. Multi-cut transits can also be done in numerous ways, differentiated by how the tow packet is broken, and where or if the powered vessel fits into the chamber with the barges. These are categorized in both the LPMS data and in ARNOLT as lockage types.

Processing times in ARNOLT as well as in LPMS are separated into sub-categories representing the various components of a lockage. These are approach (long or short), entry, chambering, and exit, and in the ARNOLT model timing for each of these categories is unique to lockage type. Approach and chambering time distributions should theoretically be identical across all lockage types, as these components of processing; traveling to the chamber itself, and the cycle of the lock chamber, are identical regardless of which lockage type is performed. (Note that these timing distributions are per-cut, rather than per-transit.) The others however will vary based on the type of lockage; a setover lockage will take more time to pack the chamber (entry).

Figure 2 - Lockage Component Times Diagram



For all lockage type/component time pairs, LPMS data on historic lockages of the corresponding type is used to build a distribution of possible times that can be sampled during simulations. In the four LPMS data years loaded, there were 28,455 lockages recorded through the project. Of these, after post-processing LPMS data to correct the issues described previously, roughly 42% were the 'straight' lockage type (coded 'S'), meaning they processed through in a single cut. A further 54% (all of which the result of data post-processing) were of the 'barge-before-tow' or 'consecutive' lockage type (coded 'BC'), indicating they processed through in multiple cuts, with tow elements only broken along a vertical axis, (for instance a tow with 4 barges strung out, processing in two cuts of two barges each). A final 4% processed through as 'knockout' lockages (coded 'K') which indicates the powered vessel was locked through in a space next to one or more barges rather than behind them. While calibration to historic lock operation in this case would be unimpacted by the absence of empirical data on other lockage types ('jack-knife' and 'setover', or 'JV'), to ensure the model is able to accurately simulate scenarios in which other lockage types would be more frequent or necessary, accurate distributions need to be manually input for these other types.

To do this, distributions were fit to empirical data from 'K' type lockages, and the model was set up to sample processing times by category from these distributions for jack-knife and setover lockages. These distribution fits are shown in the figures below.

Figure 3 - Entry Distribution, JV Lockages, Normal Distribution

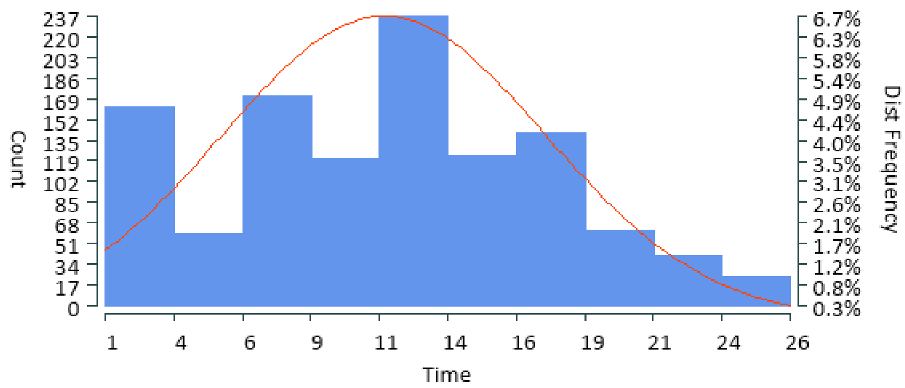
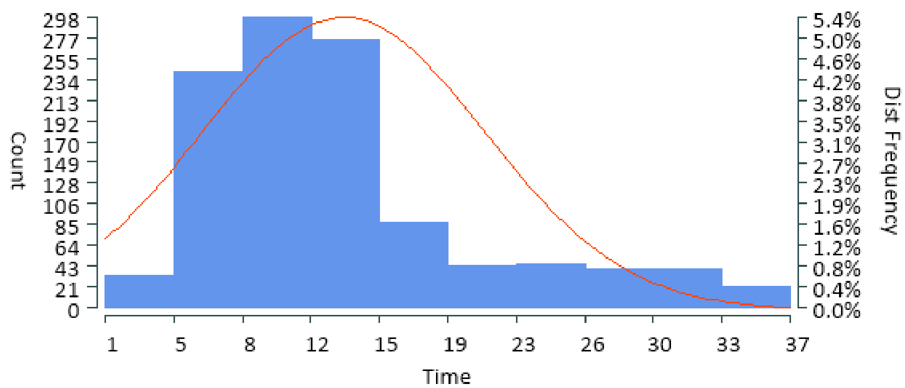


Figure 4 - Exit Distribution, JV Lockages, Normal Distribution



4. Tow Processing

In addition to the characterization of lock traffic, how the project is operated is an important component in calibrating the model. There are various elements of how a project operates represented as input parameters in ARNOLT. These include the queue service policy (first come/first served or N up/N down), chamber usage bias (when or if a chamber should be given preference), and tow assist settings.

The project was assumed to operate with a five up/five down queue service rule, as this appears consistent with the LPMS data. In analyzing the post-processed LPMS data (with re-aggregated tows) numbers of consecutively 'skipped' flotillas in a given direction were compared against the queue size in the opposite direction; for instance the number of waiting up-bound flotillas that were processed after later arriving down-bound flotillas, for a range of down-bound queue sizes. This was done for both directions, as well as in total. The results of this analysis are shown in the figures below. At low queue sizes, N cannot exceed the number of users waiting, but at higher queue sizes it continues to increase. ARNOLT, like WAM before it, does not evaluate queue service rules or operating policies as a function of queue size, but rather as a target number. For IHNC, five up/down was used in the previous WAM analysis per discussions with lock operators, and this estimate appears to be roughly consistent with the data record as well.

Figure 5 - Flotillas N Up/Down, Both Directions

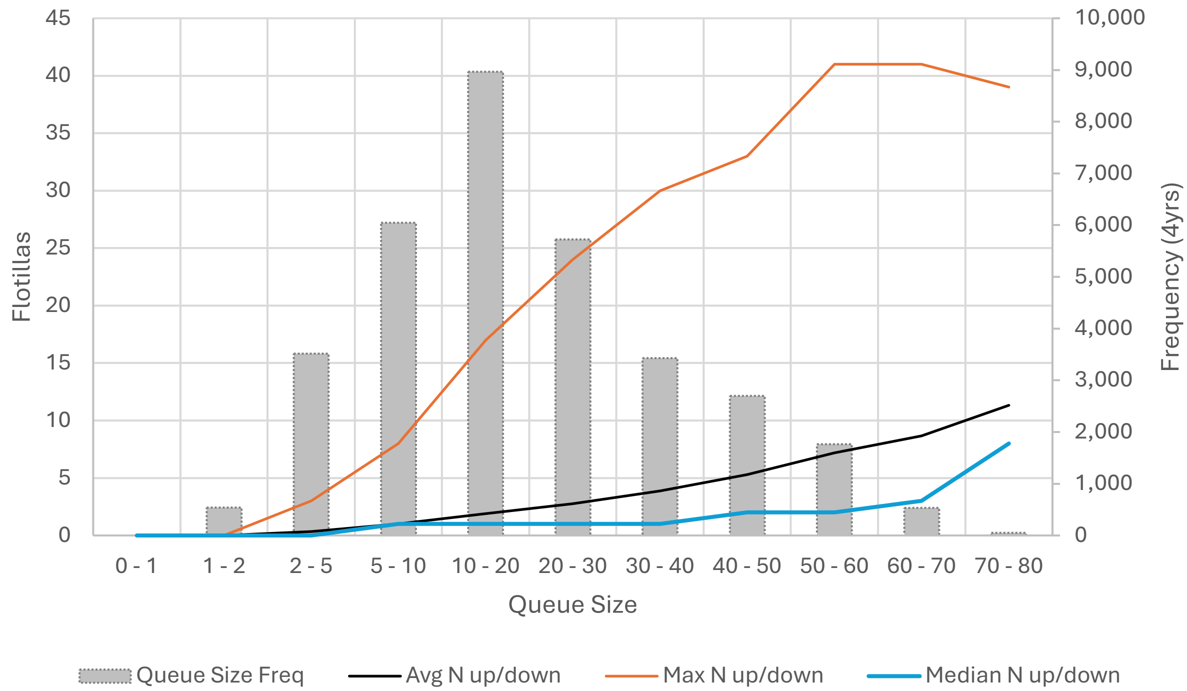


Figure 6 - Flotillas N Up/Down, Downbound

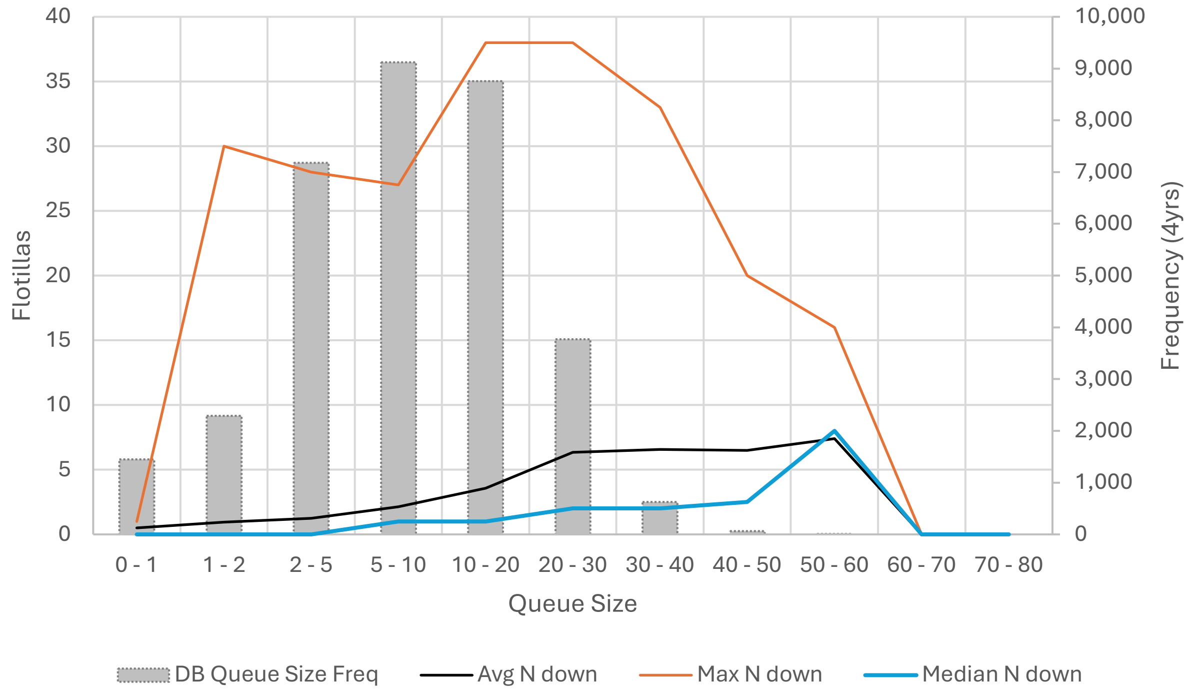
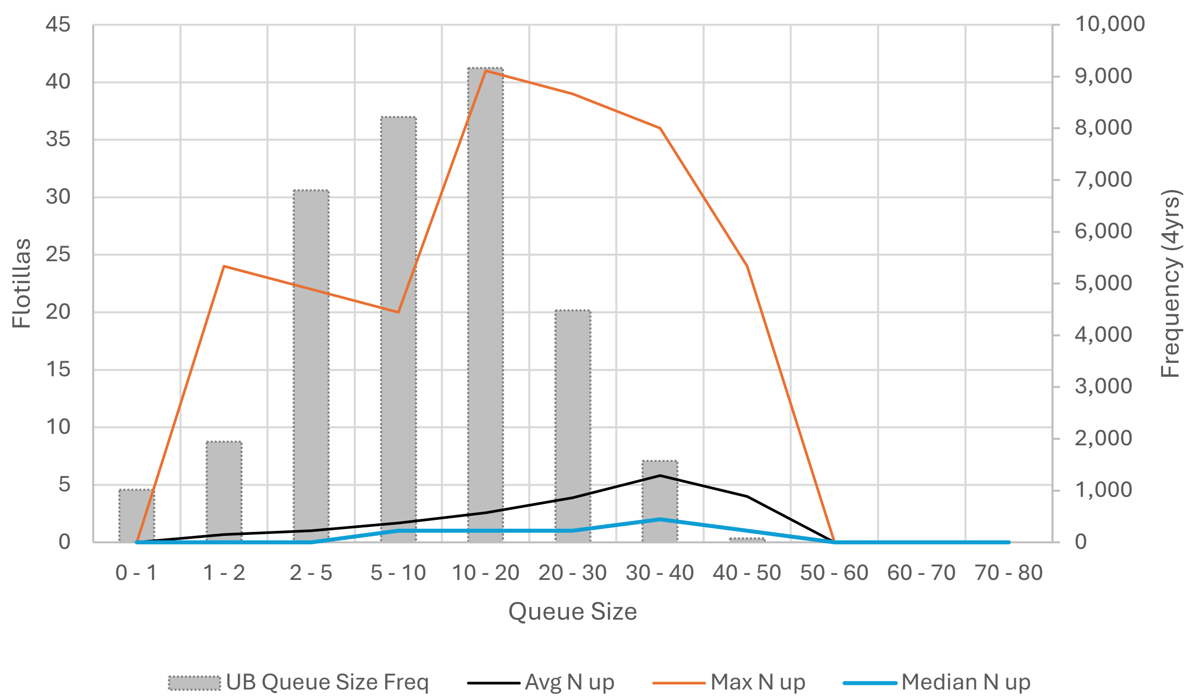


Figure 7 - Flotillas N Up/Down, Upbound



As IHNC has only one chamber, chamber prioritization and other related inputs are not applicable and were left at default values. Finally for tow assist, industry self-help with no queue threshold was used. Assist codes are not recorded in LPMS for IHNC, but this is consistent with the known operation of the project, with tows pre-configuring on either end of the channel rather than breaking and reassembling at the project itself.

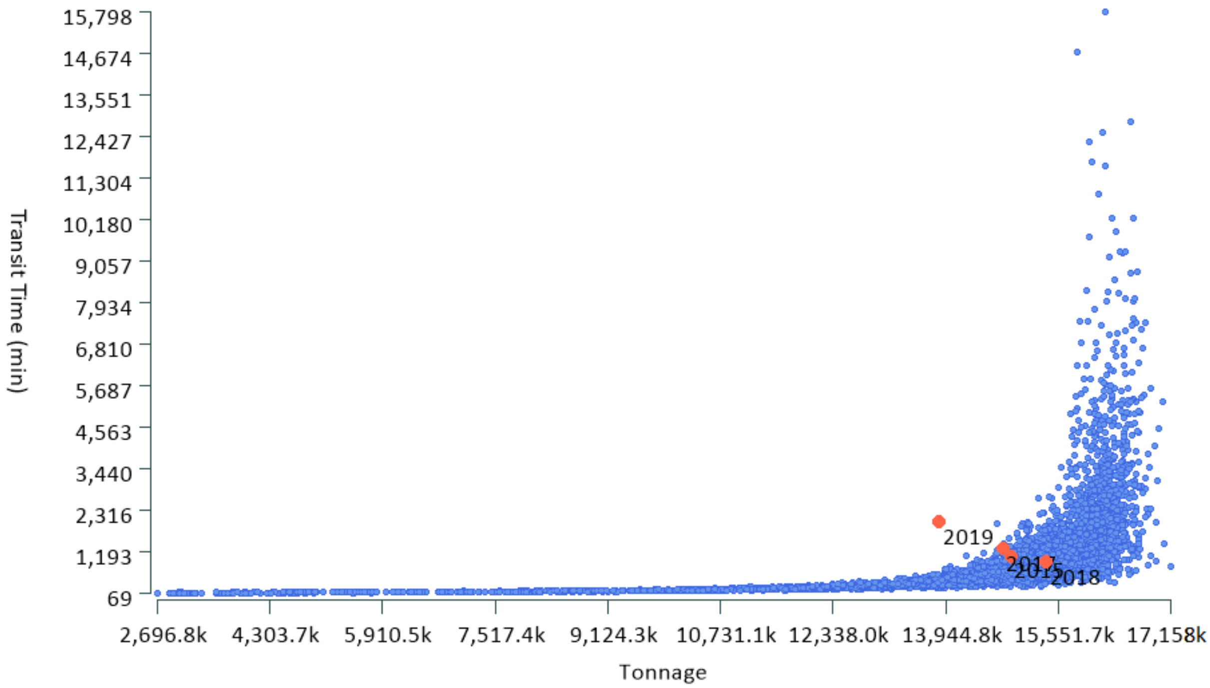
5. Flotilla Archetypes

When the project definitions are loaded, the model generates an inventory of 'flotilla archetypes'. These are essentially a series of representative tows used to reflect the range of traffic that has transited the project in loaded LPMS data years. Flotilla archetypes are the program's attempt to match the LPMS data for flotilla dimensions, seasonality, barge counts, barge dimensions, cargo, and many other parameters. When these are generated, much of the data can be pulled directly from the LPMS data used to feed the model, however there are A) multiple parameters necessary to fully characterize a flotilla that are not present in LPMS, and B) frequently multiple data errors in LPMS that can lead to the mischaracterization of some flotillas. A genetic algorithm is used to optimize flotilla archetype generation. After these flotilla archetypes are generated, that must be reviewed to ensure they accurately reflect traffic and to check for data errors. For the IHNC model, each flotilla archetype which the model's estimated simulated number of cuts did not match the number of cuts recorded in the LPMS data was identified. In most cases, the cause was inaccurate overall flotilla dimensions or barge size categories recorded in LPMS. To resolve these cases (less than two percent of the total), these archetypes were re-optimized with barge sizes or target dimensions adjusted as needed.

6. Calibration Results

Calibrating against two separate years (the two used together as the base year) presents a challenge in that simulated traffic will reflect an average of both years, making calibrating to either one individually less accurate. Below is a figure of ARNOLT simulation's average transit time and tonnage processed compared to historic data, which presents the best indication of overall model calibration:

Figure 8 - Simulated Tonnage/Transit Time Results vs Historic LPMS



As can be seen in the figure, ARNOLT simulation results (blue points) fit well with historical data (red points, labeled by year), with simulation results plotting directly through the main cluster of LPMS tonnage/transit time (2019 excepted). In 2019, which is a relative outlier compared to the other LPMS data years, there were four multi-day long closures of the project that markedly increase average transit times.

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