# Fish Passage Plan (FPP) Change Form

**Change Form # & Title**: 23IHR001 – Unit 3 Operating Range

**Date Submitted**: 10-NOV-2022

**Project**: Ice Harbor

**Requester Name, Agency**: Jon Renholds and Chris Peery, Corps NWW

**Final Action:**

**FPP Section**:

IHR section 4.3 Turbine Unit Operating Range

**Justification for Change**:

IHR Unit 3 is being rebuilt with a new Voith Kaplan runner design (adjustable blade) and is currently scheduled to return to service in early 2023. This Change Form adds the new U3 operating range to the FPP.

Based on CFD and physical modeling, flow quality in the Unit 3 draft tube is optimized for fish passage by establishing the minimum blade angle as the lower limit, which is about 200–400 cfs above the 1% lower limit. Therefore, the operating range for Unit 3 will be between the Fish Passage (FP) Lower Limit (minimum blade angle) and the 1% Upper Limit. This range may be adjusted based on results of index testing in spring 2023 and biological testing in September 2023.

During periods of minimum generation, Unit 3 may be operated at the 1% lower limit to provide more flow for spill.

**Proposed Change**:

See following pages for edits to existing FPP in track changes.

* 1. Turbine Unit Operating Range.
     1. Turbine unit flow and power output at the lower and upper limits of the ±1% peak efficiency range are defined in **Table IHR-5**. Turbine units will be operated within these ranges according to *BPA’s Load Shaping Guidelines* (**Appendix C**), as summarized below.
     2. Ice Harbor Unit 3 was rebuilt with a new adjustable-blade runner design and will have a restricted operating range within the 1%, as defined in **Table IHR-5**. Based on CFD and physical modeling, flow quality in the Unit 3 draft tube is optimized for fish passage by establishing the minimum blade angle as the lower limit, which is about 200–400 cfs above the 1% lower limit. Therefore, the operating range for Unit 3 will be between the Fish Passage (FP) Lower Limit (minimum blade angle) and the 1% Upper Limit. This range may be adjusted based on results of index testing in spring 2023 and biological testing in September 2023.

During periods of minimum generation with a single unit in use, Unit 3 may be operated at the 1% lower limit to provide more flow for spill, in accordance with **section 4.3.3.2** below.

* + 1. **In-Season: April 3–August 31 (Spring/Summer Spill for Juvenile Fish Passage).**
       1. Turbine units will be operated within ±1% of peak turbine efficiency (1% range), except under limited conditions and durations when turbines may be operated above the 1% range for the use of reserves or for TDG management during high flows (refer to **Appendix C** for more information). All required fish passage spill operations will be met prior to operating turbines above the 1% range. If in-season operation outside the 1% range is necessary, Project personnel shall record the information to provide to BPA on a weekly basis according to the *Guidelines*. Operation outside the 1% range may be necessary to:

Meet BPA load requests made pursuant to BPA's policy, statutory requirements, and *Load Shaping Guidelines* (**Appendix C**).

If the draft tube is to be dewatered (**section 4.3.7**), the unit will be operated at full load > 1% (or at speed no load < 1% if not possible to load) for a minimum of 15 minutes prior to installing tail logs to flush fish from the unit.

Operate a turbine unit solely to provide station service.

Comply with other coordinated fish measures.

* + - 1. **Minimum Generation.** During low flows, all lower Snake River projects may be required to keep one generating unit online to maintain power system reliability. The minimum generation flow range for each unit is defined in FOP Table 1 (**Appendix E**), as derived from the lower limit of the 1% range and actual unit operations. During spring and summer spill for juvenile fish passage, if there is not enough river flow to meet this generation requirement and the FOP spill target, the project will operate the first available priority unit at minimum generation and spill the remainder of outflow. Actual attainable minimum generation values may vary depending on real-time conditions.
    1. **Off-Season: September 1–April 2.** While not required to do so in the off-season, turbines will normally run within the 1% range since it is the optimum point for maximizing energy output of a given unit of water over time. Unit 3 is still recommended to operate within the range defined in **section 4.2.2**. Operation outside the 1% range is allowed if needed for power generation or other needs.

**Table IHR-5. Ice Harbor Dam Turbine Unit Power (MW) and Flow (cfs) at ±1% of Peak Turbine Efficiency (Lower and Upper Limits of 1% Range) and Operating Limits. a**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Project** | **IHR Unit 1 – with STS** | | | | | | **IHR Unit 1 – No STS** | | | | | |
| **Head** | **1% Lower Limit** | | **1% Upper Limit** | | **Operating Limit b** | | **1% Lower Limit** | | **1% Upper Limit** | | **Operating Limit b** | |
| **(feet)** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** |
| 85 | 51.7 | 8,417 | 83.6 | 13,590 | 92.8 | 16,053 | 51.9 | 8,340 | 89.9 | 14,452 | 102.6 | 16,859 |
| 86 | 52.6 | 8,443 | 84.6 | 13,585 | 94.3 | 16,077 | 52.7 | 8,367 | 91.0 | 14,447 | 103.1 | 16,715 |
| 87 | 53.4 | 8,469 | 85.6 | 13,580 | 95.7 | 16,099 | 53.5 | 8,392 | 92.0 | 14,441 | 103.6 | 16,568 |
| 88 | 54.2 | 8,494 | 86.6 | 13,574 | 97.3 | 16,144 | 54.3 | 8,417 | 93.1 | 14,436 | 104.1 | 16,420 |
| 89 | 55.0 | 8,518 | 87.6 | 13,569 | 99.0 | 16,187 | 55.1 | 8,441 | 94.2 | 14,430 | 104.5 | 16,252 |
| 90 | 55.8 | 8,542 | 88.6 | 13,563 | 100.1 | 16,158 | 55.9 | 8,465 | 95.3 | 14,424 | 104.5 | 16,034 |
| 91 | 56.5 | 8,548 | 89.8 | 13,585 | 101.0 | 16,058 | 56.6 | 8,471 | 96.5 | 14,448 | 104.5 | 15,822 |
| 92 | 57.1 | 8,554 | 90.9 | 13,607 | 101.9 | 15,960 | 57.3 | 8,477 | 97.8 | 14,471 | 104.5 | 15,614 |
| 93 | 57.8 | 8,559 | 92.1 | 13,628 | 102.8 | 15,864 | 58.0 | 8,482 | 99.0 | 14,494 | 104.5 | 15,411 |
| 94 | 58.5 | 8,565 | 93.2 | 13,649 | 103.6 | 15,769 | 58.6 | 8,488 | 100.3 | 14,516 | 104.5 | 15,213 |
| 95 | 59.2 | 8,570 | 94.4 | 13,669 | 104.5 | 15,675 | 59.3 | 8,493 | 101.5 | 14,537 | 104.5 | 15,019 |
| 96 | 59.9 | 8,589 | 95.3 | 13,662 | 104.5 | 15,425 | 60.1 | 8,511 | 102.5 | 14,530 | 104.5 | 14,845 |
| 97 | 60.7 | 8,607 | 96.3 | 13,655 | 104.5 | 15,180 | 60.8 | 8,529 | 103.6 | 14,522 | 104.5 | 14,676 |
| 98 | 61.5 | 8,624 | 97.3 | 13,648 | 104.5 | 14,941 | 61.6 | 8,546 | 104.6 | 14,515 | 104.5 | 14,509 |
| 99 | 62.2 | 8,641 | 98.2 | 13,641 | 104.5 | 14,708 | 62.4 | 8,563 | 105.7 | 14,508 | 104.5 | 14,347 |
| 100 | 63.0 | 8,658 | 99.2 | 13,634 | 104.5 | 14,481 | 63.1 | 8,580 | 106.7 | 14,500 | 104.5 | 14,187 |
| 101 | 64.0 | 8,707 | 99.9 | 13,590 | 104.5 | 14,318 | 64.1 | 8,629 | 107.4 | 14,454 | 104.5 | 14,037 |
| 102 | 65.0 | 8,756 | 100.6 | 13,547 | 104.5 | 14,158 | 65.2 | 8,677 | 108.2 | 14,408 | 104.5 | 13,890 |
| 103 | 66.0 | 8,804 | 101.3 | 13,505 | 104.5 | 14,001 | 66.2 | 8,725 | 108.9 | 14,363 | 104.5 | 13,746 |
| 104 | 67.0 | 8,850 | 102.0 | 13,463 | 104.5 | 13,847 | 67.2 | 8,771 | 109.7 | 14,319 | 104.5 | 13,605 |
| 105 | 68.0 | 8,896 | 102.6 | 13,422 | 104.5 | 13,697 | 68.2 | 8,816 | 110.4 | 14,275 | 104.5 | 13,466 |
|  | **IHR Unit 2 c – with STS** | | | | | | **IHR Unit 2 c – No STS** | | | | | |
| 85 | 77.2 | 12,179 | 87.1 | 13,753 | 89.4 | 14,254 | 77.9 | 12,193 | 88.1 | 13,795 | 91.2 | 14,392 |
| 86 | 78.5 | 12,225 | 88.3 | 13,750 | 90.8 | 14,290 | 79.1 | 12,232 | 89.4 | 13,810 | 92.7 | 14,389 |
| 87 | 79.8 | 12,265 | 89.5 | 13,759 | 92.2 | 14,333 | 80.4 | 12,272 | 90.7 | 13,835 | 94.2 | 14,509 |
| 88 | 81.1 | 12,303 | 90.8 | 13,769 | 93.6 | 14,363 | 81.7 | 12,310 | 92.1 | 13,877 | 95.6 | 14,511 |
| 89 | 82.4 | 12,339 | 92.0 | 13,776 | 95.0 | 14,474 | 82.9 | 12,336 | 93.6 | 13,924 | 97.1 | 14,500 |
| 90 | 83.7 | 12,373 | 93.2 | 13,777 | 96.4 | 14,508 | 84.1 | 12,351 | 95.1 | 13,963 | 98.6 | 14,619 |
| 91 | 85.0 | 12,399 | 94.5 | 13,778 | 97.8 | 14,526 | 85.1 | 12,349 | 96.6 | 14,006 | 100.1 | 14,643 |
| 92 | 86.1 | 12,401 | 95.8 | 13,800 | 99.2 | 14,536 | 86.3 | 12,364 | 98.0 | 14,049 | 101.5 | 14,762 |
| 93 | 86.8 | 12,354 | 96.9 | 13,803 | 100.6 | 14,623 | 87.3 | 12,366 | 98.9 | 14,007 | 103.0 | 14,787 |
| 94 | 87.5 | 12,325 | 98.3 | 13,845 | 102.0 | 14,619 | 87.9 | 12,307 | 100.3 | 14,050 | 103.5 | 14,628 |
| 95 | 88.8 | 12,381 | 99.3 | 13,835 | 103.2 | 14,568 | 89.4 | 12,368 | 101.6 | 14,062 | 103.5 | 14,300 |
| 96 | 89.8 | 12,389 | 100.8 | 13,907 | 103.5 | 14,469 | 90.6 | 12,393 | 103.0 | 14,083 | 103.5 | 14,024 |
| 97 | 90.8 | 12,389 | 102.0 | 13,917 | 103.5 | 14,229 | 92.1 | 12,455 | 104.3 | 14,110 | 103.5 | 13,782 |
| 98 | 91.9 | 12,384 | 103.6 | 13,970 | 103.5 | 13,977 | 93.4 | 12,491 | 105.8 | 14,146 | 103.5 | 13,576 |
| 99 | 92.9 | 12,374 | 105.1 | 14,006 | 103.5 | 13,744 | 94.2 | 12,466 | 107.2 | 14,182 | 103.5 | 13,404 |
| 100 | 93.8 | 12,364 | 106.4 | 14,033 | 103.5 | 13,543 | 95.4 | 12,501 | 108.6 | 14,225 | 103.5 | 13,254 |
| 101 | 94.7 | 12,358 | 107.8 | 14,068 | 103.5 | 13,365 | 96.7 | 12,541 | 110.0 | 14,266 | 103.5 | 13,114 |
| 102 | 95.8 | 12,364 | 109.2 | 14,088 | 103.5 | 13,205 | 97.5 | 12,520 | 111.4 | 14,310 | 103.5 | 12,979 |
| 103 | 96.9 | 12,370 | 110.5 | 14,107 | 103.5 | 13,061 | 98.3 | 12,503 | 112.9 | 14,357 | 103.5 | 12,852 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Project** | **IHR Unit 3 c – with STS** | | | | | | | | **IHR Unit 3 c – No STS** | | | | | | | |
| **Head** | **1% Lower Limit** | | **FP Lower Limit** | | **1% Upper Limit** | | **Operating Limit** | | **1% Lower Limit** | | **FP Lower Limit** | | **1% Upper Limit** | | **Operating Limit** | |
| **(feet)** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** | **MW** | **cfs** |
| 85 | 55.3 | 8,657 | 57.3 | 8,894 | 86.1 | 13,473 | 94.1 | 14,920 | 55.1 | 8,585 | 57.3 | 8,858 | 89.0 | 13,862 | 93.6 | 14,681 |
| 86 | 56.4 | 8,708 | 58.0 | 8,904 | 87.4 | 13,501 | 95.5 | 14,990 | 56.2 | 8,647 | 58.2 | 8,878 | 90.4 | 13,903 | 95.1 | 14,709 |
| 87 | 57.3 | 8,748 | 59.0 | 8,935 | 88.9 | 13,572 | 96.6 | 15,007 | 57.4 | 8,714 | 59.2 | 8,914 | 91.3 | 13,855 | 96.4 | 14,703 |
| 88 | 58.0 | 8,754 | 59.6 | 8,930 | 90.4 | 13,626 | 97.9 | 14,992 | 58.3 | 8,733 | 60.0 | 8,927 | 93.2 | 13,966 | 97.6 | 14,699 |
| 89 | 58.6 | 8,741 | 60.6 | 8,953 | 92.0 | 13,712 | 99.3 | 14,944 | 59.0 | 8,744 | 60.7 | 8,921 | 94.8 | 14,035 | 98.9 | 14,708 |
| 90 | 59.3 | 8,734 | 61.4 | 8,953 | 93.9 | 13,831 | 100.6 | 14,944 | 59.8 | 8,749 | 61.6 | 8,938 | 96.6 | 14,138 | 100.2 | 14,725 |
| 91 | 60.0 | 8,741 | 62.2 | 8,963 | 95.5 | 13,904 | 101.9 | 14,937 | 60.5 | 8,755 | 62.4 | 8,939 | 98.4 | 14,237 | 101.5 | 14,721 |
| 92 | 60.8 | 8,749 | 62.9 | 8,962 | 97.2 | 13,980 | 103.1 | 14,949 | 61.3 | 8,767 | 63.1 | 8,945 | 100.3 | 14,331 | 103.1 | 14,765 |
| 93 | 61.8 | 8,784 | 63.8 | 8,983 | 98.3 | 13,975 | 104.4 | 14,966 | 62.2 | 8,794 | 63.9 | 8,962 | 101.5 | 14,346 | 104.5 | 14,795 |
| 94 | 62.9 | 8,828 | 65.2 | 9,071 | 99.5 | 13,981 | 104.5 | 14,797 | 63.2 | 8,826 | 64.9 | 8,993 | 102.9 | 14,374 | 104.5 | 14,617 |
| 95 | 63.8 | 8,858 | 66.5 | 9,157 | 101.0 | 14,018 | 104.5 | 14,587 | 64.2 | 8,862 | 65.8 | 9,029 | 104.4 | 14,426 | 104.5 | 14,435 |
| 96 | 64.7 | 8,877 | 67.8 | 9,225 | 103.1 | 14,152 | 104.5 | 14,375 | 65.1 | 8,895 | 66.8 | 9,066 | 105.9 | 14,468 | 104.5 | 14,253 |
| 97 | 65.6 | 8,909 | 69.1 | 9,308 | 105.6 | 14,355 | 104.5 | 14,180 | 66.1 | 8,930 | 67.8 | 9,105 | 107.6 | 14,549 | 104.5 | 14,075 |
| 98 | 66.4 | 8,936 | 70.1 | 9,349 | 107.8 | 14,502 | 104.5 | 13,999 | 67.0 | 8,954 | 68.8 | 9,135 | 109.2 | 14,602 | 104.5 | 13,903 |
| 99 | 67.5 | 8,981 | 70.8 | 9,342 | 109.2 | 14,519 | 104.5 | 13,827 | 67.8 | 8,969 | 69.8 | 9,170 | 111.0 | 14,689 | 104.5 | 13,738 |
| 100 | 68.4 | 9,002 | 71.3 | 9,310 | 110.9 | 14,593 | 104.5 | 13,666 | 68.7 | 8,999 | 70.9 | 9,211 | 113.0 | 14,797 | 104.5 | 13,575 |
| 101 | 69.3 | 9,021 | 71.9 | 9,290 | 112.5 | 14,636 | 104.5 | 13,515 | 69.7 | 9,030 | 71.7 | 9,218 | 114.5 | 14,831 | 104.5 | 13,418 |
| 102 | 70.3 | 9,047 | 72.6 | 9,283 | 114.0 | 14,684 | 104.5 | 13,372 | 70.7 | 9,058 | 72.4 | 9,219 | 115.8 | 14,846 | 104.5 | 13,275 |
| 103 | 71.4 | 9,093 | 73.2 | 9,254 | 114.9 | 14,641 | 104.5 | 13,236 | 71.8 | 9,102 | 73.4 | 9,249 | 117.3 | 14,872 | 104.5 | 13,138 |

NOTE: The lower limit for Unit 3 is set at the Fish Passage (FP) Lower Limit, which is about 200-400 cfs above the 1% Lower Limit. The intent is to optimize flow conditions in the draft tube for fish that pass via Unit 3. During minimum generation, Unit 3 will be operated at the 1% Lower Limit to provide more flow for spill. See **section 4.2.2** for more information.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Project** | **IHR Unit 4 (Blades Locked @ 22.3°) – with STS d** | | | | | | | | | | **IHR Unit 4 (Blades Locked @ 22.3°) – No STS d** | | | | | | | | | | |
| **Head** | **Lower Limit** | | | **Upper Limit** | | | **Operating Limit b** | | | | **Lower Limit** | | | | **Upper Limit** | | | | **Operating Limit b** | | |
| **(feet)** | **MW** | **cfs** | | **MW** | **cfs** | | **MW** | | **cfs** | | **MW** | | **cfs** | | **MW** | | **cfs** | | **MW** | **cfs** | |
| 85 | 76.2 | | 12,151 | 80.0 | | 12,687 | | 82.8 | | 13,195 | | 76.4 | | 12,147 | | 80.1 | | 12,667 | 83.3 | | 13,243 |
| 86 | 77.7 | | 12,228 | 81.3 | | 12,726 | | 83.8 | | 13,196 | | 77.8 | | 12,225 | | 81.4 | | 12,708 | 84.4 | | 13,259 |
| 87 | 79.1 | | 12,302 | 82.5 | | 12,764 | | 84.9 | | 13,197 | | 79.3 | | 12,299 | | 82.6 | | 12,747 | 85.6 | | 13,274 |
| 88 | 80.5 | | 12,374 | 83.8 | | 12,800 | | 85.9 | | 13,196 | | 80.7 | | 12,371 | | 83.9 | | 12,784 | 86.7 | | 13,287 |
| 89 | 82.0 | | 12,441 | 85.0 | | 12,836 | | 86.9 | | 13,193 | | 82.2 | | 12,439 | | 85.5 | | 12,869 | 87.8 | | 13,298 |
| 90 | 83.3 | | 12,494 | 86.3 | | 12,870 | | 87.9 | | 13,186 | | 83.5 | | 12,493 | | 86.4 | | 12,856 | 88.9 | | 13,305 |
| 91 | 84.5 | | 12,523 | 87.5 | | 12,905 | | 88.9 | | 13,184 | | 84.7 | | 12,520 | | 87.7 | | 12,893 | 90.1 | | 13,317 |
| 92 | 85.6 | | 12,547 | 88.5 | | 12,893 | | 89.9 | | 13,181 | | 85.8 | | 12,547 | | 88.6 | | 12,883 | 91.2 | | 13,330 |
| 93 | 86.7 | | 12,562 | 89.4 | | 12,882 | | 91.0 | | 13,179 | | 87.0 | | 12,565 | | 89.6 | | 12,873 | 92.3 | | 13,342 |
| 94 | 87.8 | | 12,574 | 90.6 | | 12,915 | | 92.0 | | 13,177 | | 88.0 | | 12,579 | | 90.9 | | 12,908 | 93.5 | | 13,355 |
| 95 | 88.8 | | 12,580 | 91.6 | | 12,903 | | 93.0 | | 13,173 | | 89.1 | | 12,590 | | 91.8 | | 12,897 | 94.6 | | 13,365 |
| 96 | 89.9 | | 12,597 | 92.5 | | 12,895 | | 94.2 | | 13,203 | | 90.2 | | 12,606 | | 92.8 | | 12,892 | 96.0 | | 13,411 |
| 97 | 91.0 | | 12,614 | 93.8 | | 12,932 | | 95.4 | | 13,231 | | 91.3 | | 12,624 | | 94.0 | | 12,929 | 97.3 | | 13,454 |
| 98 | 92.1 | | 12,633 | 94.7 | | 12,923 | | 96.6 | | 13,255 | | 92.4 | | 12,643 | | 95.0 | | 12,923 | 98.6 | | 13,493 |
| 99 | 93.2 | | 12,654 | 95.9 | | 12,958 | | 97.8 | | 13,278 | | 93.5 | | 12,665 | | 96.2 | | 12,959 | 99.9 | | 13,531 |
| 100 | 94.3 | | 12,679 | 97.2 | | 12,990 | | 98.9 | | 13,297 | | 94.7 | | 12,691 | | 97.5 | | 12,993 | 101.2 | | 13,565 |
| 101 | 95.4 | | 12,687 | 98.1 | | 12,986 | | 100.1 | | 13,317 | | 95.7 | | 12,695 | | 98.5 | | 12,986 | 102.3 | | 13,570 |
| 102 | 96.4 | | 12,694 | 99.1 | | 12,982 | | 101.3 | | 13,339 | | 96.7 | | 12,699 | | 99.4 | | 12,979 | 103.4 | | 13,577 |
| 103 | 97.4 | | 12,700 | 100.1 | | 12,978 | | 102.5 | | 13,364 | | 97.7 | | 12,701 | | 100.4 | | 12,973 | 104.5 | | 13,587 |
| 104 | 98.4 | | 12,705 | 101.0 | | 12,974 | | 103.7 | | 13,389 | | 98.7 | | 12,703 | | 101.3 | | 12,966 | 105.6 | | 13,597 |
| 105 | 99.4 | | 12,711 | 102.3 | | 13,010 | | 104.9 | | 13,413 | | 99.7 | | 12,706 | | 102.6 | | 13,000 | 106.7 | | 13,604 |
|  | **IHR Units 5, 6 (Blades Locked @ 23.8°) – with STS d** | | | | | | | | | | | **IHR Units 5, 6 (Blades Locked @ 23.8°) – No STS d** | | | | | | | | | |
| 85 | 77.9 | | 12,446 | 83.6 | | 13,280 | | 87.3 | | 13,956 | | 79.2 | | 12,624 | | 83.0 | | 13,156 | 87.7 | | 13,974 |
| 86 | 79.6 | | 12,565 | 85.0 | | 13,343 | | 88.5 | | 13,970 | | 80.6 | | 12,691 | | 84.3 | | 13,199 | 89.1 | | 14,023 |
| 87 | 81.3 | | 12,678 | 86.4 | | 13,404 | | 89.6 | | 13,980 | | 82.0 | | 12,752 | | 85.6 | | 13,240 | 90.5 | | 14,074 |
| 88 | 82.9 | | 12,768 | 87.9 | | 13,464 | | 90.8 | | 13,989 | | 83.3 | | 12,807 | | 86.9 | | 13,281 | 91.9 | | 14,124 |
| 89 | 84.4 | | 12,848 | 89.3 | | 13,522 | | 91.9 | | 13,995 | | 84.6 | | 12,847 | | 88.2 | | 13,320 | 93.3 | | 14,171 |
| 90 | 85.6 | | 12,880 | 90.4 | | 13,530 | | 93.0 | | 13,997 | | 85.8 | | 12,878 | | 89.5 | | 13,358 | 94.7 | | 14,214 |
| 91 | 87.1 | | 12,957 | 91.9 | | 13,589 | | 94.2 | | 14,007 | | 87.0 | | 12,900 | | 90.8 | | 13,396 | 96.3 | | 14,276 |
| 92 | 88.6 | | 13,033 | 93.3 | | 13,646 | | 95.3 | | 14,017 | | 88.1 | | 12,921 | | 91.8 | | 13,386 | 97.8 | | 14,335 |
| 93 | 90.2 | | 13,109 | 94.4 | | 13,654 | | 96.5 | | 14,029 | | 89.3 | | 12,941 | | 93.1 | | 13,422 | 99.3 | | 14,397 |
| 94 | 91.7 | | 13,185 | 95.9 | | 13,710 | | 97.7 | | 14,041 | | 90.4 | | 12,956 | | 94.1 | | 13,411 | 100.9 | | 14,455 |
| 95 | 93.3 | | 13,260 | 97.4 | | 13,765 | | 98.9 | | 14,053 | | 91.5 | | 12,966 | | 95.4 | | 13,446 | 102.4 | | 14,512 |
| 96 | 94.1 | | 13,230 | 98.2 | | 13,739 | | 100.0 | | 14,062 | | 92.4 | | 12,951 | | 96.4 | | 13,438 | 103.3 | | 14,486 |
| 97 | 94.9 | | 13,199 | 99.1 | | 13,712 | | 101.1 | | 14,073 | | 93.3 | | 12,939 | | 97.4 | | 13,430 | 104.3 | | 14,460 |
| 98 | 95.6 | | 13,167 | 100.3 | | 13,732 | | 102.3 | | 14,080 | | 94.2 | | 12,925 | | 98.7 | | 13,466 | 105.2 | | 14,430 |
| 99 | 96.4 | | 13,134 | 101.2 | | 13,705 | | 103.4 | | 14,088 | | 95.1 | | 12,911 | | 99.7 | | 13,458 | 106.1 | | 14,401 |
| 100 | 97.1 | | 13,097 | 102.0 | | 13,678 | | 104.5 | | 14,096 | | 96.0 | | 12,905 | | 101.0 | | 13,493 | 106.9 | | 14,371 |
| 101 | 98.1 | | 13,086 | 102.9 | | 13,651 | | 105.7 | | 14,099 | | 97.2 | | 12,931 | | 101.9 | | 13,483 | 107.8 | | 14,332 |
| 102 | 99.0 | | 13,075 | 104.1 | | 13,668 | | 106.8 | | 14,100 | | 98.4 | | 12,957 | | 102.9 | | 13,474 | 108.6 | | 14,294 |
| 103 | 99.9 | | 13,063 | 104.9 | | 13,641 | | 107.8 | | 14,102 | | 99.6 | | 12,980 | | 103.9 | | 13,465 | 109.4 | | 14,257 |
| 104 | 100.8 | | 13,052 | 105.7 | | 13,613 | | 108.9 | | 14,103 | | 100.8 | | 13,004 | | 105.2 | | 13,498 | 110.2 | | 14,217 |
| 105 | 101.7 | | 13,040 | 106.9 | | 13,628 | | 110.1 | | 14,107 | | 102.0 | | 13,026 | | 106.2 | | 13,488 | 111.0 | | 14,176 |

1. Values provided by HDC (Mar 2007), as updated for Units 2 and 3 with new runner design (Sep 2021 and Nov 2022, respectively) and Units 4, 5, 6 with locked blades (May 2022). Flow (cfs) was calculated based on turbine efficiency, project head, and power output (MW).
2. “Operating Limit” is the maximum safe operating point based on cavitation or generator limit (added Feb 2018). IHR Units 1-3 generator limit restricts turbine output at higher heads. Values shaded in gray indicate Operating Limit is below the Upper Limit.
3. Units 2 and 3 were rebuilt with a new Voith runner design to reduce impacts to fish (completed May 2019 and Feb 2023, respectively). Unit 2 is fixed-blade (non-adjustable) and Unit 3 is adjustable-blade .
4. Units 4, 5, and 6 have locked runner blades and restricted operating ranges until the blade seals are repaired or replaced. Table values are based on abbreviated index tests for U4 (hydraulic) in 2021, U5 (welded) in 2017, and U6 (hydraulic) in 2019, as updated May 2022.

**Comments**:

10-NOV-2022 FPOM Meeting:

Swank - would like more detail on why the flow quality at the lower 1% is bad.

Renholds - it was qualitatively looked at with beads and dye and determined to be a worse operating point. There was instability in the draft tube below the FP lower limit. Draft tube hydraulics were rougher, more unsteady/turbulent. Assume this relates to fish impacts. The FP lower limit is purely for fish. The unit can run at the 1% lower limit, but modeling shows it’s more turbulent in the draft tube which is assumed to be worse for fish.

Keep this on the agenda for the December FPOM.

8-DEC-2022 FPOM Meeting:

Peery and Wright added language to allow operating below the FP lower limit, down to the lower 1%, during min gen. This language meets the intent of having the FP range as a “soft constraint.”

Wright will distribute to FPOM for review and discussion at the 12-JAN-2023 FPOM.

**Record of Final Action**: