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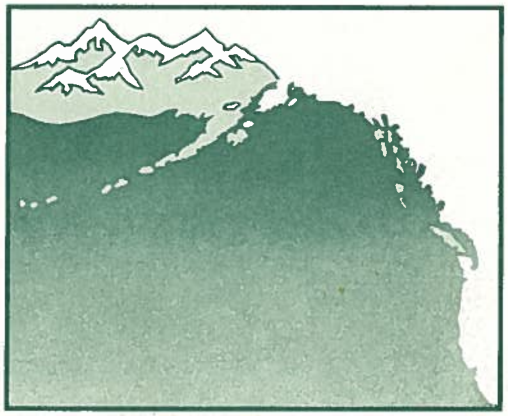

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SCHOOL OF FISHERIES

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Submitted 22 June 1989

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EXECUTIVE SUMMARY

This is the final report of a study that measured low frequency sound generated by four Columbia River hydroelectric projects. Low frequency sound in the range perceived by downstream migrating fish was measured at: Bonneville Dam First and Second Powerhouses, Lower Granite Dam and McNary Dam. The report describes the characteristics and sources of underwater sound.

Sound is characterized by frequency and sound pressure level, defined as SPL = $20\log_{10}(p/p_{ref})$, where p and p_{ref} are measured and reference sound pressures. The SPL in turbine entrances differed between powerhouses. Bonneville Second had the lowest SPL, while Bonneville First had the highest SPL. Each project had a distinctive acoustic signature that, with the exception of Bonneville Second, was constant between turbines at any given project.

Far field sound measurements indicate that fish approaching the Bonneville project perceive sounds of the dam twice as far from Bonneville First as from the Second Powerhouse. In addition, these same sound pressures occur farther out in the forebay at McNary than they do at Bonneville First.

Sound pressure levels in front of the dams, designated the near field, were about 10 dBs lower than in the fish bypass slots. In addition, bypass slot spectra had a number of acoustic peaks that were absent in the near field. Sound levels increased about 10 dBs from just below the surface to the level of the turbine entrance.

The acoustic signatures in the bypass slots of Bonneville Second were a function of the bypass configurations of the bypass slots. In addition, distinct low frequency peaks appeared to increase in intensity closer to the Submersible Traveling Screen (**STS**), and it appears that water flow through the gap between the STS and turbine intake ceiling may produce these peaks.

Measurements at a turbine hatch with the airborne microphone (-3 foot elevation) at Bonneville Second showed peaks of energy at 18 Hz and 63 Hz.

Coherence and phase data indicate that the acoustic environment at Bonneville Second is complex, and much of the acoustic phenomena is unexplainable. However, sound at 18 Hz and 30 Hz is coherent at almost all locations at the dam suggesting turbines are the primary source for these frequencies.

Fish moving with the flow would experience higher rates of SPL increase in front of the trashrack at Bonneville Second compared to Bonneville First and McNary Dam. In addition, Bonneville Second had a peak of sound energy localized to the bypass slot and STS frame ranging from 120-160 Hz. Water rushing through the gap at the STS may be the cause of this peak. This peak was absent at the trashrack.

This report provides a background for future laboratory studies on the response of fish to sounds at dams. If fish exhibit clear attraction or repulsion responses to sound, further studies may be warranted.

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ACKNOWLEDGMENTS

We wish to thank the Army Corps of Engineers for assistance in carrying out this project. We individually wish to thank for their assistance in carrying out this project; Robert Mangne, James Kuskie, and Edward Willits from Bonneville Dam; and John Ferguson from the Portland District Office of the Army Corps of Engineers.

INTRODUCTION

Studies conducted at Columbia River hydroelectric projects suggest that a portion of downstream migrating salmonids avoid the Submersible Traveling Screen (STS) and pass through turbines (Anderson 1988a; Hays 1988; Williams et al. 1988). Since a turbine entrance is virtually dark, fish must avoid diversion structures through detection of flow changes and sounds produced by the structures. A model of fish trajectories at a hydroelectric facility suggested that fish avoid passing through a trashrack when an STS is located directly behind the trashrack (Anderson 1988b). The hypothesis was proposed that an STS may generate low frequency sounds that fish perceive at a distance. If fish elicit an avoidance response to sounds of an STS, the Fish Guidance Efficiency (FGE) might be improved by altering the distribution of sound in a diversion structure.

In order to better understand the relationship between sound and fish guidance, we measured the underwater acoustic fields at Bonneville First and Second Powerhouses, McNary and Lower Granite Dams. This study will provide background information to assess the response of fish to the types of sounds generated by fish diversion systems at hydroelectric projects.

The conclusion section of this report follows the introduction and summarizes the findings of this study. The next section of the report, the discussion, presents the methods used for measuring the sound produced at the dams, followed by the results of the study, and finally the interpretation of these results.

CONCLUSIONS

Low frequency sound in the range perceived by downstream migrating fish was measured in fish bypass slots at: Bonneville First and Second Powerhouses, Lower Granite and McNary Dams; in the forebays of Bonneville and McNary Dams; and on the trashrack and STS (submersible traveling screen) frame at Bonneville Second.

In general, each project had a distinctive acoustic signature that was reproducible between turbines at any given project with identical bypass configurations. Bonneville First was a "noisier" powerhouse, whereas Bonneville Second was the "quiet" powerhouse.

Forebay and reservoir measurements indicated that threshold Sound Pressure Level (SPL) for salmonids was twice as far from Bonneville First as it was from Bonneville Second. This threshold SPL was even further away at McNary.

Sound pressure levels in front of the dams, designated the near field, were about 10 dBs lower than in the fish bypass slots. Sound levels increased about 10 dBs from just below the surface to the level just below the STS at Bonneville Second.

The spectral patterns or acoustic signatures of the various bypass configurations at Bonneville Second were as follows: STS and bar screen acoustic signatures were similar, and the acoustic signature at Bonneville Second was altered by the experimental ceiling extensions and by the gap size at the top of the STS.

A distinct low frequency peak from 120-160 Hz at Bonneville Second increased in intensity closer to the STS. Water rushing through the gap at the top of STS may produce this peak.

Peaks at 18 Hz and 63 Hz peak were detected at the access hatch below the turbine blades at Bonneville Second. This suggests that the turbine is the source of these low frequency peaks detected in all water measurements.

Coherence and phase data indicate that the acoustic environment at Bonneville Second is complex, and much of the acoustic phenomena is unexplainable. Multiple sound generators and reflectors within the dam could conceivably startle juvenile salmonids and decrease FGE.

Assuming fish move with flow patterns, they would experience higher rates of sound pressure increase entering Bonneville Second compared to Bonneville First and McNary Dam. In addition, the apparent STS-generated peak between 120 Hz and 160 Hz may alter fish behavior as they move through the trashrack.

Although the present study identified sounds that are possibly associated with turbines and bypass screens, it is difficult to speculate on how a change in screen configuration will affect these sounds. Resulting effects on fish guidance are even more difficult to infer. Since extended screens are being considered for some projects, however, such speculations are useful.

The fact that different screen configurations had unique sound characteristics suggests that extended screens will produce measurable changes in turbine entrance sounds. Since an extended STS could decrease the effective area of the turbine entrance, and consequently increase the velocity below the STS, noise levels below the STS also may increase, reflecting a change in velocity. On the other hand, the 130 Hz noise, apparently produced by the flow through the gap at the top of the STS, may increase in intensity if the velocity through the gap increases. Thus, an extended STS may increase the average noise level below the STS and increase the 130 Hz noise above the STS.

There is insufficient information on fish responses to sound to infer how such changes would affect fish guidance efficiency. Scenarios can be constructed that increase, decrease or have no effect on fish guidance. If fish are not affected by low frequency sound then, noise changes due to extended screens would not affect FGE. If fish were attracted to loud sounds, extended screens may move them deeper in the water column and the effect of sound on FGE would be negative. If, on the other hand, fish were attracted to lower levels of sound, extended screens could have a positive effect on FGE. The apparent gap noise may complicate the problem. If fish were repelled by the noise, the FGE could be negatively affected; if they were attracted to the noise, the FGE could be positively affected.

These scenarios suggest that sound may have a variety of effects on fish guidance. Since we do not know how fish respond to the sounds of the dams, further studies are required to identify if any of the scenarios are realistic. Laboratory studies can provide a cost-effective starting point by demonstrating if smolts exhibit attraction, repulsion or no response to the sounds of the dams. If a clear reaction is observed, further studies might be warranted to determine how sound can be optimized to improve fish guidance. If, in a laboratory, smolts do not respond to the sounds, then further studies would not appear warranted.

DISCUSSION

The discussion section of this report consists of three parts: methods, results and interpretation of results. The methods section describes how and where the sound was measured, and what the project configurations were during the measurements. The results section describes the various acoustic signatures of the different dams, and their associated bypass configurations.

METHODS

Low frequency sound (5 to 1000 Hz) was measured at Bonneville Dam First and Second Powerhouses, McNary and Lower Granite Dams (Figs. 1 and 2). At each powerhouse measurements were made in the fish bypass slots, which contained either an STS, or in one case a bar screen. At Bonneville Second and McNary, measurements were made down the face of the projects. At Bonneville Second Powerhouse measurements were made below the ceiling extension, on the STS frame, at a hatch just below the turbine blades (-3 ft elevation relative to sea level), and at different elevations on the trashrack (Fig. 2).

Three hydrophones were used to monitor the sound at Bonneville Second, unit 15B. The first hydrophone was fastened to a steel mounting bracket welded to sled that moved up and down the north concrete pier of intake 15B. Measurements were made at 9 elevations relative to sea level (-18, -8, 2, 12, 22, 32, 41, 51, 61 foot elevations). The second hydrophone was fastened to a bracket welded to the STS frame at the 3 foot elevation. The third hydrophone was lowered in the bypass slot of unit 15B to the 32 foot elevation (see Fig. 21).

Sound was monitored with B & K model 88101 hydrophones. Hydrophone output signal gain was adjusted to maximize the signal-to-noise ratio for recording on analog magnetic audio tape. Signals were recorded on a Bell and Howell model 4010 analog tape recorder, analyzed in the field with a Hewlett-Packard 3561 Spectrum Analyzer, and plotted with a Hewlett-Packard model 7470A two pen plotter. For the multiple hydrophone measurements, spectral coherence and phasing were determined with a Rockland 5820A cross channel spectrum analyzer.

In the forebay of Bonneville and McNary Dams, sound was measured with a portable Sony Walkman® unit capable of measuring sound frequencies down to 25 Hz with the B & K hydrophone. The hydrophone was lowered to a depth of 25 feet and recordings were made while the boat drifted with the current.

In order to differentiate between particle velocity and sound pressure, two hydrophones were attached to a wooden frame and lowered into a bypass slot. The hydrophones were 2.5 feet apart such that fluctuations due to turbulence would be decorrelated between the hydrophones. Thus, fluctuations produced by sound pressure would exhibit a strong correlation between the two hydrophones (signal correlation of 1) and fluctuations produced by turbulence would yield a low degree of correlation between the hydrophones (correlation near zero, Buck and Green 1980). The signal correlation was better than 0.9 over the analysis band of 10-200 Hz, indicating that measurements taken were negligibly contaminated with particle velocity fluctuations (Buck and Green 1980).

The intensity of sound in this report is expressed in logarithmic scales called sound levels. One reason for using this logarithmic scale is to compress the range of numbers required to describe the wide range of sound intensities, which if expressed as pressure would range from 10^{-12} to 10 watts/m^2. A second reason, is that the human ear subjectively judges the relative loudness of two sounds by the ratio of their intensities, a logarithmic behavior. By the standard convention, sound level is expressed as a **S**ound **P**ressure **L**evel (**SPL**) and is related to sound pressure by the equation:

$$SPL = 20\log_{10}(p/p_{ref})$$

where p is the pressure in Pascals (1 Pa = 1 Nm^{-2} = 10 μbar = 10 dyn cm^{-2}) and p_{ref} is the reference pressure, 1 Pa. For humans, SPL is expressed as decibels relative to a reference pressure of 20 μPa. This reference pressure is the minimum pressure that a human can detect over most frequencies. Sound pressure level was normalized to a bandwidth of 1 Hz and units expressed as dBs relative to 1 Pascal (dBs re. 1 Pa). The instrument output was in dBV. This was converted to dBs re. 1 Pa in order to normalize the dBV readings to a common scale, namely dBs re. 1Pa:

$$SPL = \text{dBs re. 1 Pascal} = \text{dBV} - \text{gain} + 65.3 - 10\log_{10}(\text{BandWidth})$$

The gain was a function of the recording equipment settings, 65.3 was a hydrophone voltage sensitivity constant, and bandwidth was a function of the frequency range sampled.

The change in SPL as a function of distance from the turbines at McNary and Bonneville hydroelectric projects was determined. Average spectral energy for each spectrum was calculated from 100-1000 and 20-200 Hz at Bonneville, and 20-200 Hz at McNary by integrating the spectra at various distances from the turbine. The distances were: 138, 168, 183, 213, 303, 4053, and 26,493 feet at McNary; 61, 223, and 3033 feet at Bonneville Second; and 231, and 3855 feet at Bonneville First.

The change in the average SPL as a function of distance from the turbines was determined at McNary and Bonneville Dams. Average SPL expresses the change in sound level over a wide frequency range. This provides a better measure of the difference in noise levels of the dams since SPL is specific to a frequency band, 1 Hz for this study. Average SPL was calculated from 100-1000 and 20-200 Hz at Bonneville Dams and 20-200 Hz at McNary Dam. Average SPL was calculated using the following formula:

$$\overline{SPL} = 10\mathrm{Log}_{10}\,[\frac{1}{n}\,\Sigma\;10^{SPL(i)/10}]$$

where SPL(i) is the SPL at frequency i and n is the number of frequencies sampled. Sound pressure levels were sampled every 20 and 100 Hz at Bonneville and every 20 Hz at McNary Dam.

A regression of average SPL against distance from the turbine was determined at each project to describe the acoustic environment in front of the dams. A regression was performed for each data set in order to determine the "best fit" equation for propagation. The equation for sound propagation is:

$$SPL = a + b\,(\log x)$$

where a is the intercept, b is the logarithmic slope, and x is the distance from the source.

Coherence and phase were determined by normalizing cross-correlations between different pairs of hydrophones at Bonneville Second. Time series of the noise were decomposed using fourier transforms into components at discrete frequencies, since phase is only applicable to signals with a single frequency. Coherence of one is considered perfect, whereas a coherence of zero represents no correlation for a given frequency. Coherence and phase data indicates whether specific locations within the powerhouse are receiving sound from a common source.

RESULTS

Results of the study were placed into five categories: General comparison between dams, sound distributions in the forebays of Bonneville and McNary Dams, sound in the near field of Bonneville Second Powerhouse, sound generated by the various bypass configurations at

Bonneville Second Powerhouse, and rates of sound pressure increase at McNary and Bonneville Dams. Configurations of the bypass systems during measurements are given in Table 1, power generation specifications of the dams are summarized in Table 2, and Appendix A lists the characteristics of all the sites sampled.

The greatest sensitivity for hearing in salmonids falls between 50 and 250 Hz (Hawkins and Johnstone 1978), and perception is severely diminished above 380 Hz (Fig. 3, upper curve). In this frequency range it appears fish use sound pressure and particle velocities to identify nearby objects, schooling activities of con-specifics, and occurrence of predators and prey. Compared to humans, salmonids have poor hearing on the basis of perceivable frequency range and sensitivity to sound pressure (Fig. 3). Human infants are capable of detecting sounds from 20-20,000 Hz, and at SPL's much lower than that of salmonids. For example, in Figure 3, a human would require about -80 dBs re. 1 Pa SPL to hear a 160 Hz tone, while a salmonid would require about -20 dBs. Therefore, the salmonid requires close to a thousand fold increase in SPL to hear the same 160 Hz tone.

General Comparisons Between Dams

Low frequency spectra at the four powerhouses were distinct and reproducible (Fig. 4). This was evidenced both by coherence and phase data and by the stability of spectra at a given location over time. Maximum SPL occurred at 30 and 70 Hz at Bonneville First Powerhouse, about 10 Hz at Lower Granite, and about 20 Hz at McNary. The acoustic signature of Bonneville Second Powerhouse was different from the other powerhouses with four peaks at: 30, 63, 85, and 125 Hz.

The 200 Hz frequency spectra at Bonneville Second had a number of peaks. The 1000 and 10,000 Hz spectra gradually decreased in intensity as a function of increasing frequency. Slight differences in the spectra were observed at about 400 to 500 Hz (Fig. 5).

Measurements down the face of Bonneville Second Powerhouse and Lower Granite Dam indicated that frequency spectra were different from those in the fish bypass slots. The SPL's at the face were lower than levels in the fish bypass slots. In addition, SPL's at the face of Bonneville Second Powerhouse were lower than those at the face of Lower Granite (Fig. 6).

Forebay and Reservoir Sounds

Forebay sound measurements at Bonneville Dam indicated the highest SPL's were within line of sight of the dam. The effect is evident in Figure 6 where average SPL's were 6.1 dBs greater in the line of sight (Station 3 vs. 4, Fig. 7). The frequency spectra 50 yards in front of Bonneville First and Second Powerhouses and McNary Dam had different low frequency characteristics.

McNary exhibited a low frequency roll-off at about 200 Hz while Bonneville SPL's rolled-off at about 100 Hz (Fig. 8).

The logarithmic slope of the SPL as a function of distance for McNary was -13.2 (Figure 9). For Bonneville First the slope was -22.4. A slope of -15 would be expected based on laboratory computations of sound propagation through water (Urich 1969). Hawkins and Johnstone (1978) found that Atlantic salmon (*Salmo salar*) were most sensitive to a 160 Hz pure tone, and the threshold for this frequency was -20 dBs re. 1 Pa. Therefore, we used this sound pressure as a benchmark for the low frequency hearing threshold of salmonids. The region in the river where project noise would first exceed minimum audible field thresholds of salmonids is shown for Bonneville and McNary Dams (Fig. 10). At Bonneville, this region of perception is 1,350 yards from the First Powerhouse and 760 yards from the Second. At McNary Dam this region was 2,500 yards from the powerhouse.

Near Field Sounds

Sound pressure levels in front of the dams, designated the near field, were about 10 dBs lower than in the fish bypass slots. Near field measurements were made down the bulkhead and trashrack, and below a ceiling extension. In addition, bypass slot spectra had a number of peaks that were absent in both the ceiling extension and bulkhead near field measurements (Fig. 11, 12). Measurements made down the water column down the face of the dam indicated that sound levels increased about 10 dBs from just below the surface to the level of the turbine entrance (Fig. 13, 14).

Sound propagation in the near field of Bonneville Second declined logarithmically as a function of distance (Fig. 9).

Airborne measurements made at the access hatch below the turbine blades of unit 15 at Bonneville Second showed a number of peaks in SPL, with the largest occurring at 18, 63, and 400 Hz (Fig. 15). Although data was not collected for the same area at Bonneville First, we walked through the area and noted the deafening SPL compared to Bonneville Second. The 18 and 63 Hz peak measured in this area suggests that the turbine is the source of these peaks at Bonneville Second. Since the 63 Hz peak is broader than the expected AC line noise at 60 Hz, it is very unlikely that line noise is the sole contributor to the measured SPL from 50-80 Hz.

Guidance System Sounds

The pivot point elevation of the STS had a measurable effect on sound in the fish bypass slot. In general, an STS in the lowered position increased sound levels. The increase was particularly marked at 63, 85, and 125 Hz (Fig. 16).

A comparison of sound in the fish bypass slot with the STS motor on and off showed no measurable spectral difference.

A comparison of a bar screen and an STS in the lowered position indicated the two spectra were nearly identical in the range 0 to 200 Hz (Fig. 17).

An STS in the lowered position, with a normal trashrack, had an acoustic signature similar to that observed with a vertical distribution frame (VDF) with a streamlined trashrack. The VDF exhibited higher SPL's at 85 and 300 Hz (Fig. 18).

The ceiling extension altered the amplitude of the spectral peaks measured in the fish bypass slot. The extension increased peaks at 30 and 125 Hz and decreased the peak at 85 Hz (Fig. 19).

Background noise generated by adjacent intakes is illustrated by a comparison of noise in a fish bypass slot with the turbine running to the noise in a slot with the turbine shut down. Figure 20 compares the SPL's in turbine 16 to those in turbine 11. At the time, turbines 11, 12, 13 and 20 were operating.

A comparison of the spectra at the +12 elevation on the trashrack, +3 elevation on the STS frame and +32 elevation in the bypass slot at Bonneville second revealed a broad peak from 120-160 Hz that was present only on the STS frame and bypass slot spectra (Fig. 21). In addition, the STS frame location had a sharp peak of energy at 50 Hz that was not present at the other locations sampled.

A comparison of the spectra as a function of depth on the trashrack at Bonneville second showed an increase in SPL from 0-30 Hz, no change from 30-120 Hz, and a slight increase from 120-200 Hz as the hydrophone was lowered deeper in the water column (Fig. 22).

Rates of Sound Pressure Increase Near the turbine intake

Estimation of the rate of SPL increase experienced by a fish moving with the current, was accomplished by calculating the difference in SPL at the trashrack and 10 feet from the trashrack. The time required to move this 10 foot distance was calculated for each project based on turbine intakes velocity measurements (Jensen 1987). The difference of SPL was then divided by time in seconds which gave dBs per second (Table 3). The rate of SPL increase in this 10 foot region was greatest at Bonneville Second, and lowest at McNary Dam (Table 3). In addition, measurements taken at Bonneville Second indicate that a fish moving from the trashrack to the STS pivot point, experiences a 0.54 dBs/second rate of sound pressure increase. This increase is from 120-160 Hz.

FUTURE ANALYSIS

This study has characterized the essential sound field experienced by fish approaching and entering dams on the Columbia River. The importance of these sound features in fish guidance and diversion requires an understanding of how fish respond to these stimuli. Two steps are being taken to develop this understanding. First, at the request of the Army Corps of Engineers Portland District, a literature survey will be conducted to obtain all applicable information on the response of fish to sound stimuli. Second, a preliminary laboratory study funded by the University of Washington Applied Physics Laboratory, will be conducted to determine the response of fish to the sounds of the dams. This study will be conducted in a raceway using rainbow trout *(Oncorhynchus mykiss,* formerly *Salmo gairdneri).*

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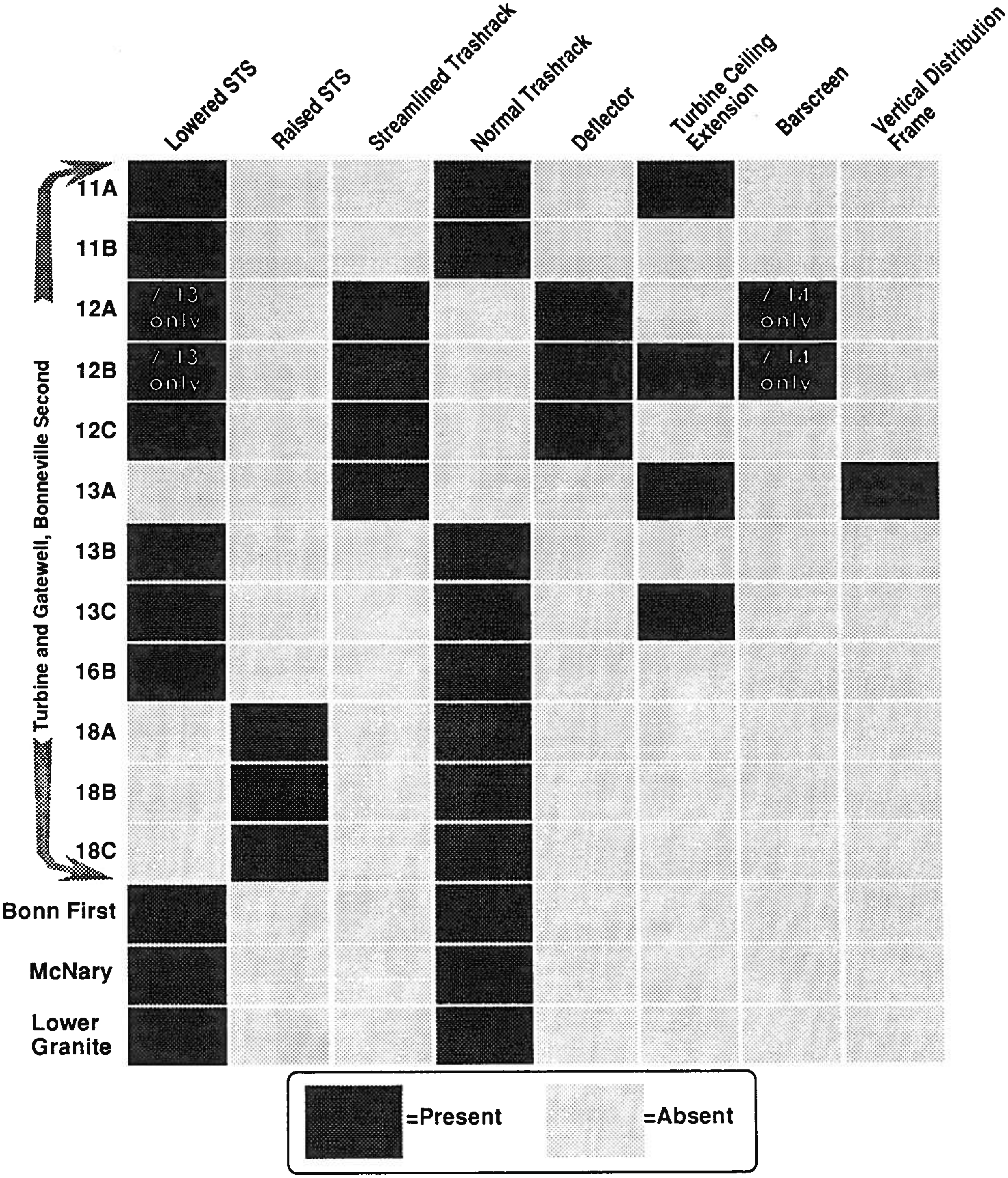
TABLES AND FIGURES



		Lowered STS	Raised STS	Streamlined Trashrack	Normal Trashrack	Deflector	Turbine Ceiling Extension	Barscreen	Vertical Distribution Frame
Turbine and Gatewell, Bonneville Second	11A	■	░	░	■	░	■	░	░
	11B	■	░	░	■	░	░	░	░
	12A	■ / 13 only	░	■	░	■	░	■ / 14 only	░
	12B	■ / 13 only	░	■	░	■	■	■ / 14 only	░
	12C	■	░	■	░	■	░	░	░
	13A	░	░	■	░	░	■	░	■ [illegible]
	13B	■	░	░	■	░	░	░	░
	13C	■	░	░	■	░	■	░	░
	16B	■	░	░	■	░	░	░	░
	18A	░	■	░	■	░	░	░	░
	18B	░	■	░	■	░	░	░	░
	18C	░	■	░	■	░	░	░	░
Bonn First		■	░	░	■	░	░	░	░
McNary		■	░	░	■	░	░	░	░
Lower Granite		■	░	░	■	░	░	░	░

■ =Present ░ =Absent

Table 1. -- Bypass system configurations of Bonneville First and Second, McNary, and Lower Granite Projects.

Table 2. Power generating characteristics at the four projects while measurements were taken.

Project	Turbines running	Total cfs	Output per turbine (MW)	Total output (MW)
Bonneville I	8	88,000	50	400
Bonneville II	4	61,000	68	272
McNary	11	119,020	66	730
Lower Granite	2	42,200	150	300

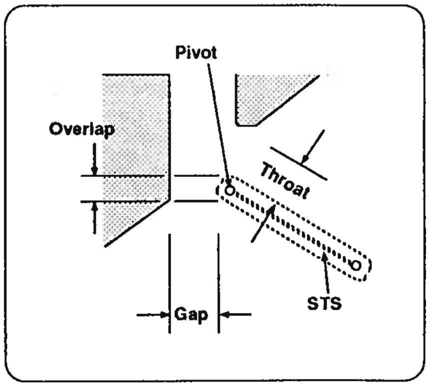
Table 3. Water velocities, sound pressure slopes and rates of increase at Bonneville First and Second, and McNary dams. Velocities estimated from Jensen (1987).

Project	Distance from Turbine (ft)	Distance from trashrack (ft)	Velocity (ft/s)	Rate of increase (dBs/s)
Bonneville I	91	10	1.7	0.19
Bonneville II	83	10	3.0	0.26
McNary	103	10	1.6	0.09
Bonn II (120-160 Hz)	73	0	1.5	0.54

Project	Velocity Information			Specific STS Information						
	Nominal Turbine Discharge (cfs per unit)	Bay Width of STS slot*	Bay Width of Trashrack	Operating Angle (deg)	Pivot pt. to Trashrack (ft)	Pivot pt. Elev (ft)	Gap (in)	Throat (in)	Overlap (in)	Potential Angles (deg)
Bonneville first	14,000	21'-4"	21'-4"	47°	31'	40.5'	12"	36"	15"	47,53,60,67
Bonneville second	20,000	20'-0"	25'-8"	60°	23'	23.9'	7"	27.5"	14 5/8"	45,50,55,60,65
McNary	14,500	20'-0"	20'-0"	60°	43'	273.8'	10 7/8"	39 7/8"	25 3/4"	45,50,55,60,65
Lower Granite	21,500	21'-0"	25'-3"	55°	55'	635.5'	5 5/8"	37 5/8"	14 3/4"	45,50,55,60,65

*3 bays for each turbine unit.

Note: Length of all STS's is 20.36' measured out to out of mesh.



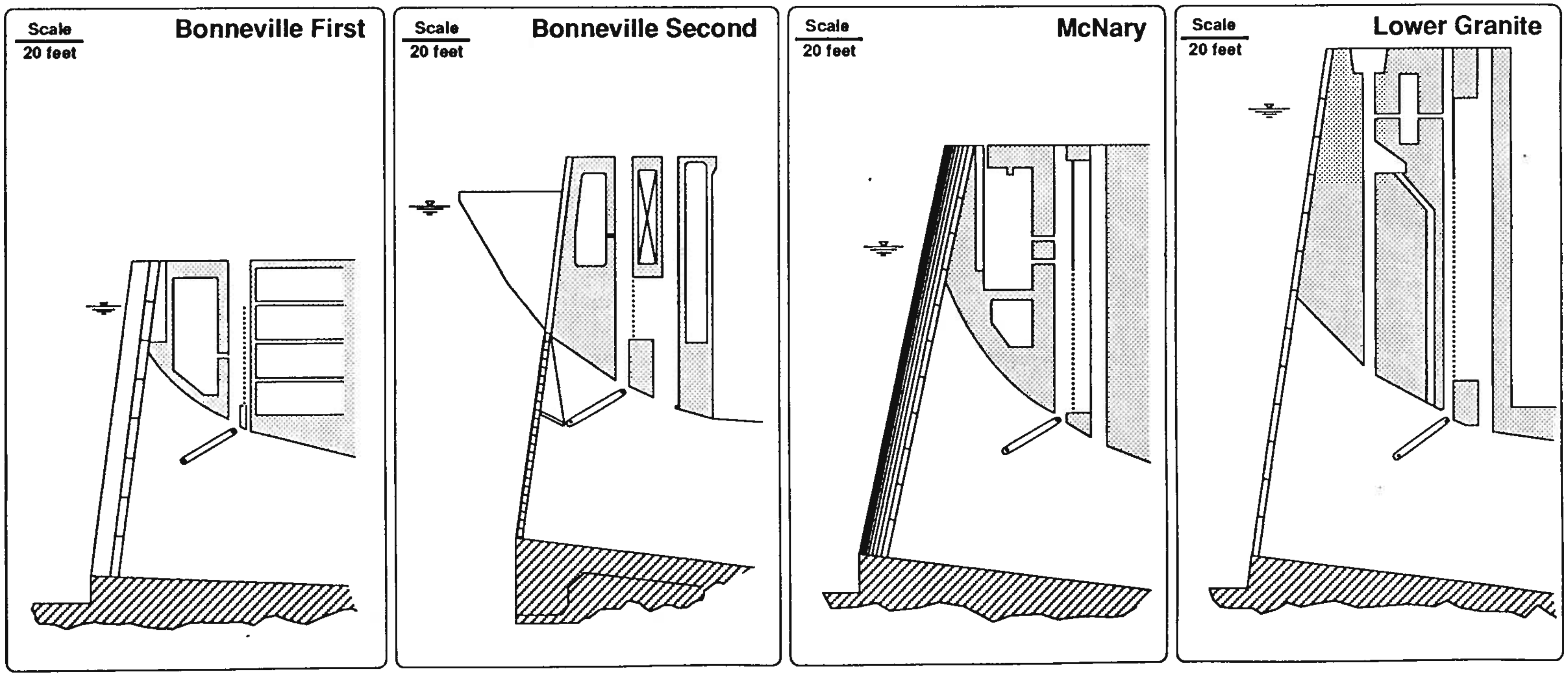


Figure 1. -- Comparison of project geometries.

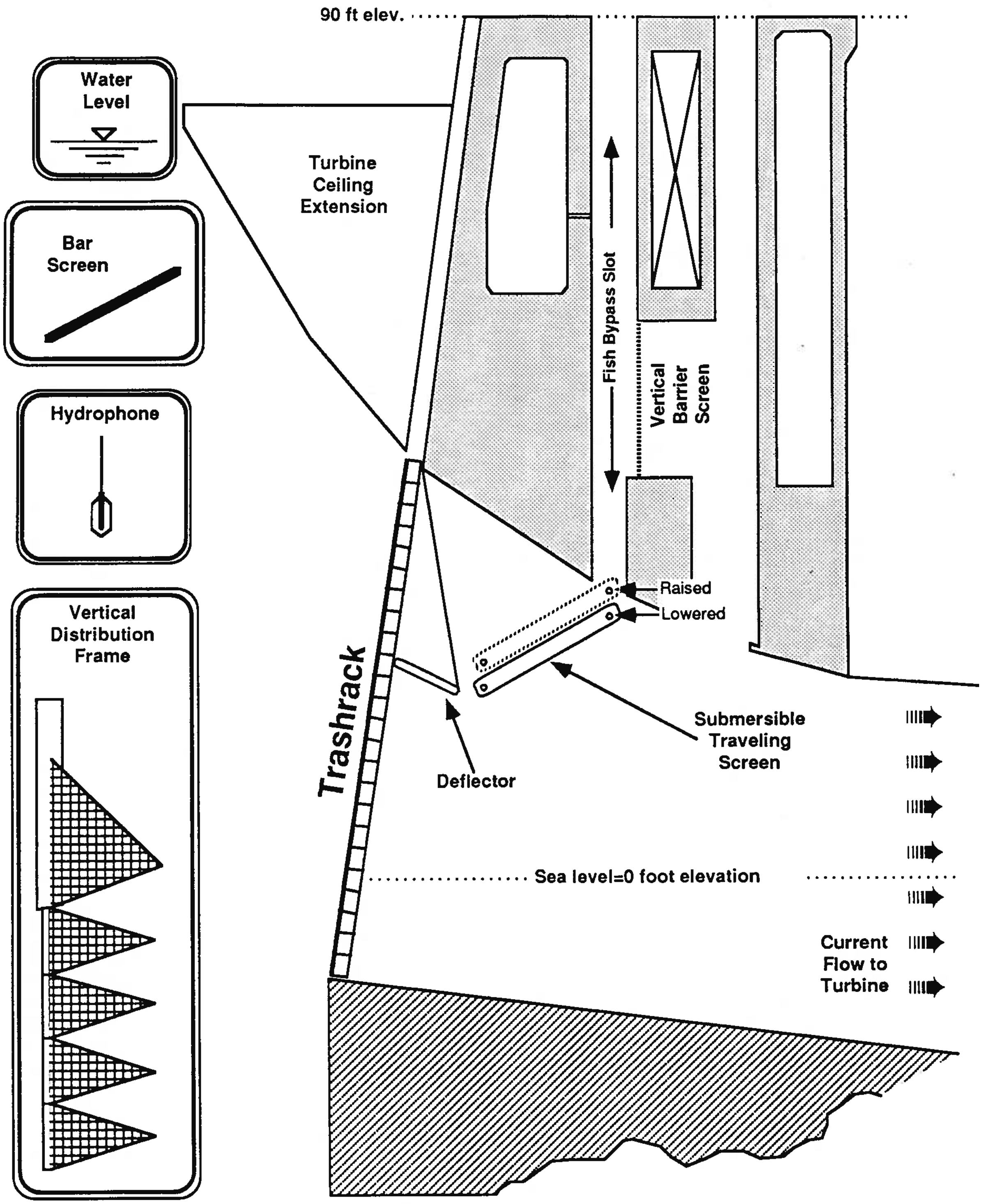


Figure 2. -- Cross Section of Powerhouse II, Bonneville Dam.

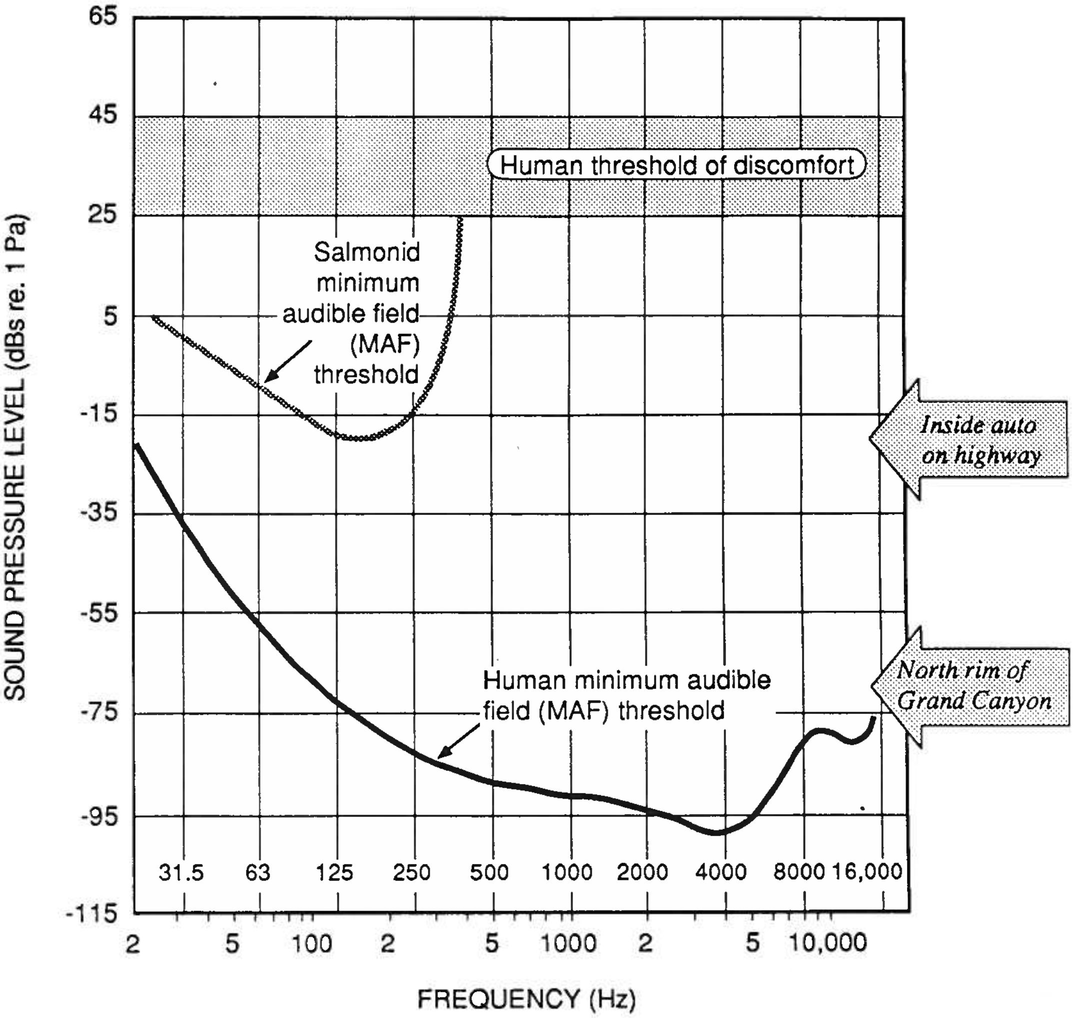


Figure 3. -- Comparison of salmonid and human sensitivity to sound from 20 to 16,000 Hz. MAF represents the minimum sound pressure at which the given frequency is detectable.

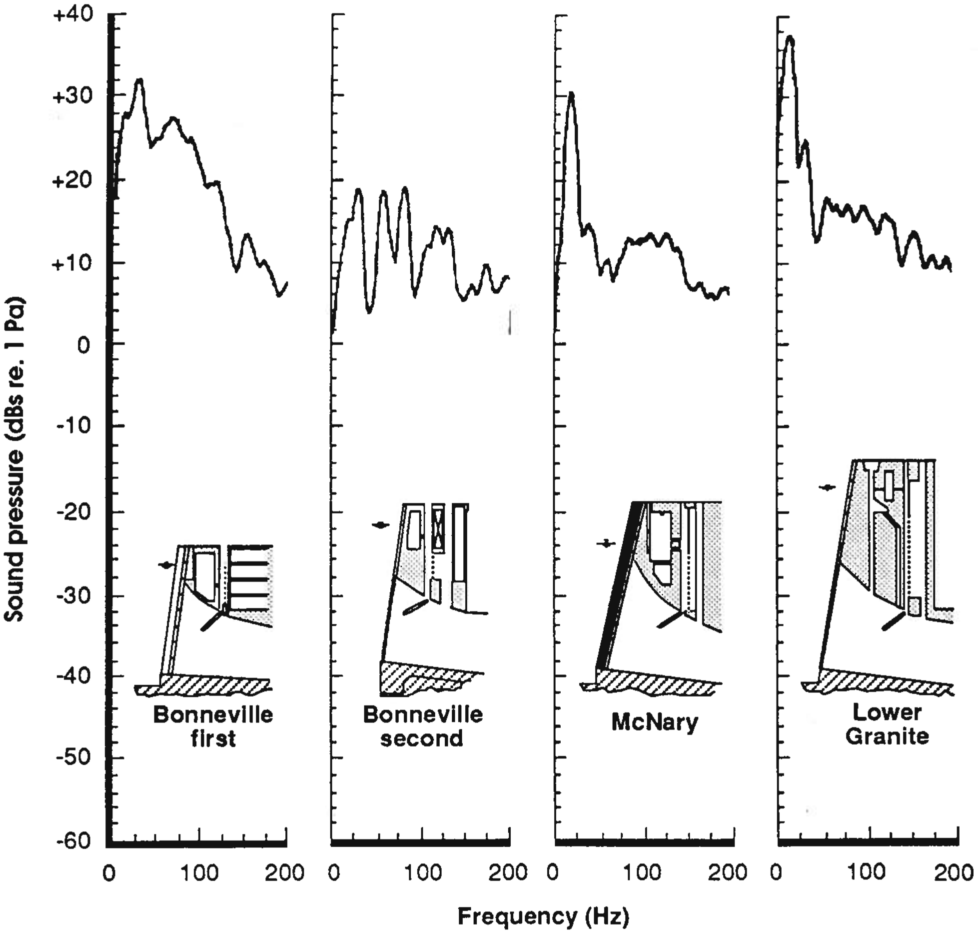


Figure 4. -- Comparison of sound spectra recorded in bypass slot at listed projects. Cross sections of each project shown below corresponding spectra, 0-200 Hz in each case.

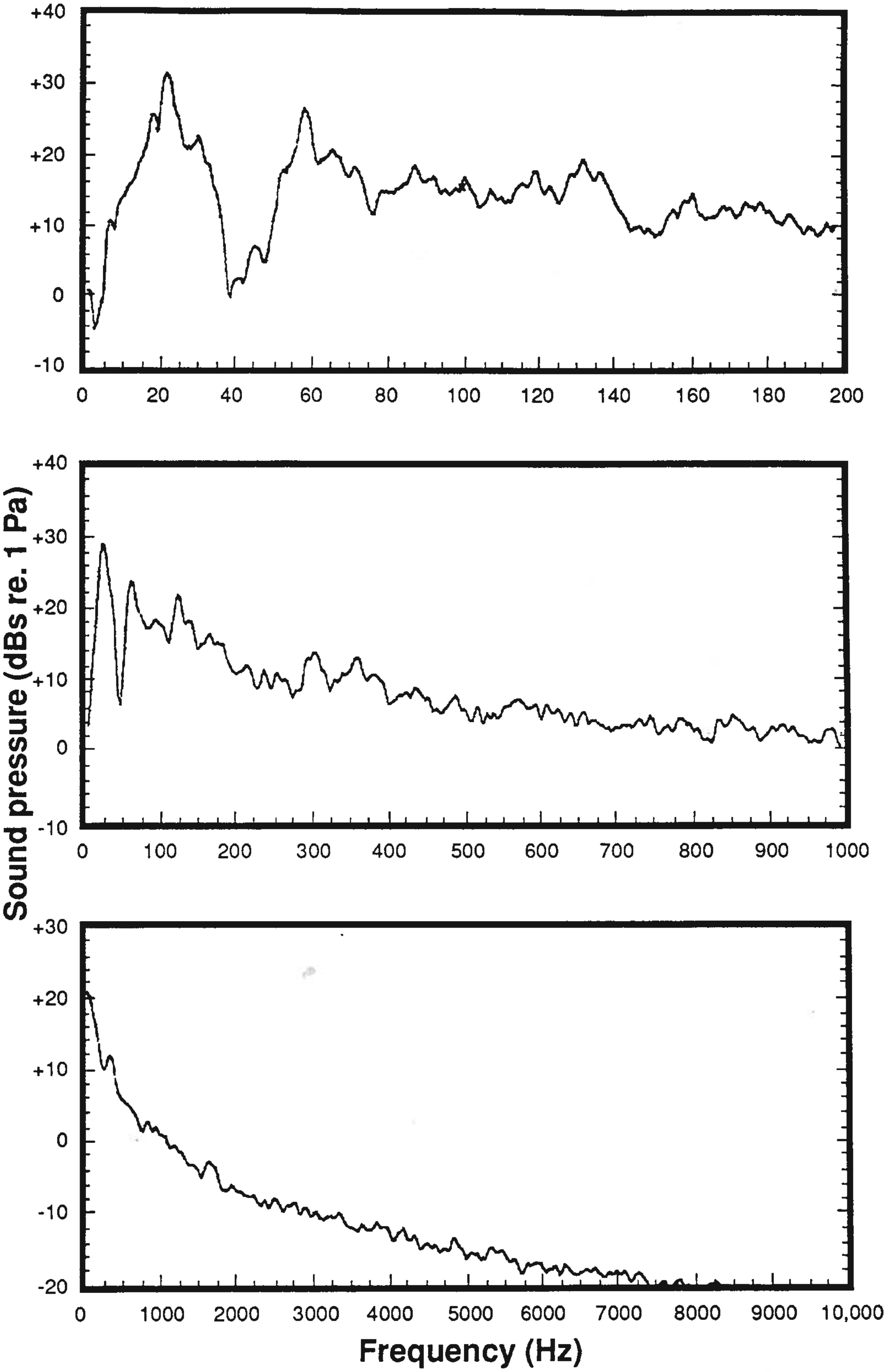


Figure 5. -- Comparison of sound spectra (0-200, 0-1000 and 0-10,000 Hz) recorded in bypass slot of Bonneville Second (Turbine 12, gatewell C).

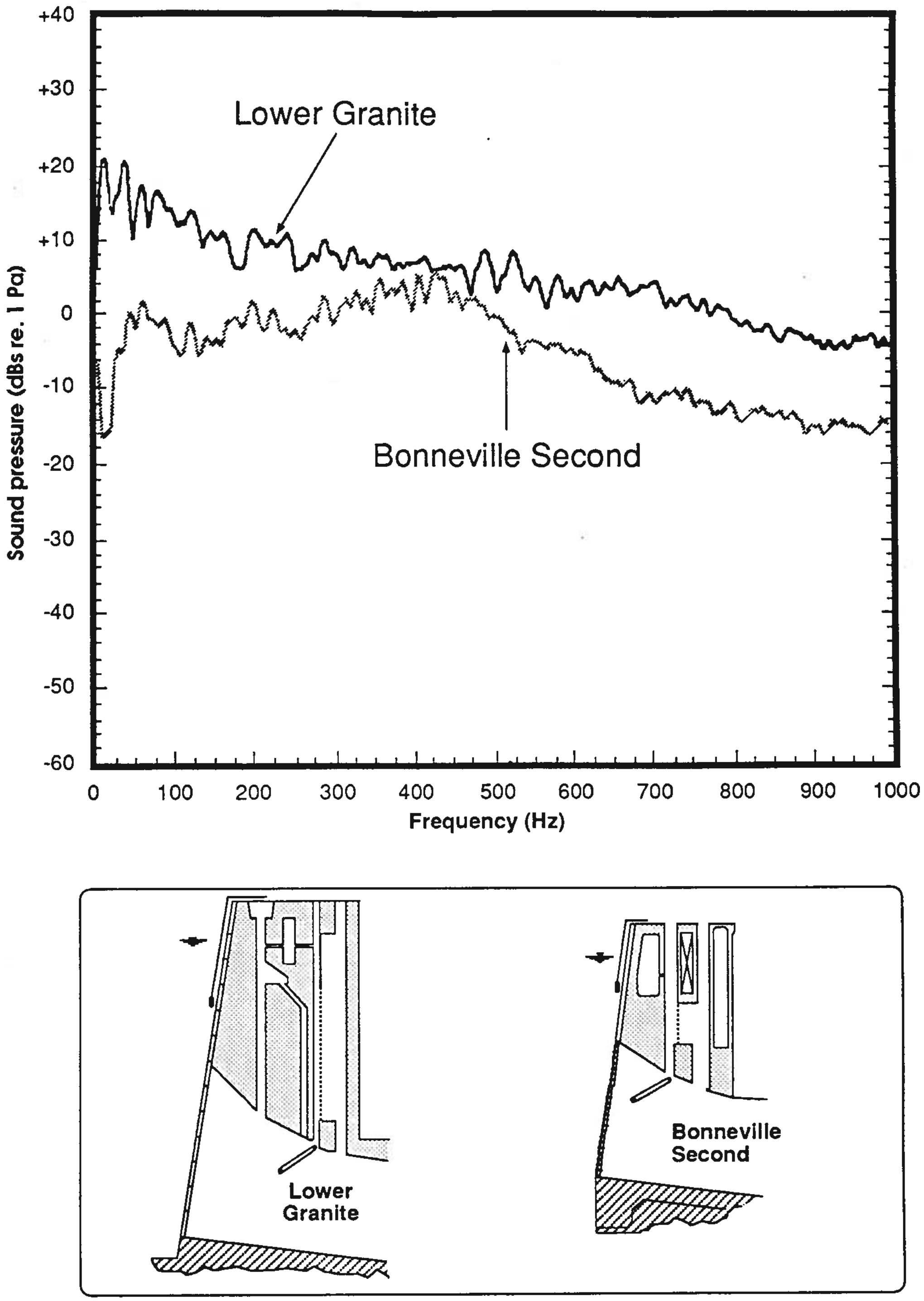


Figure 6. -- Comparison of sound spectra recorded at bulkhead of illustrated projects.

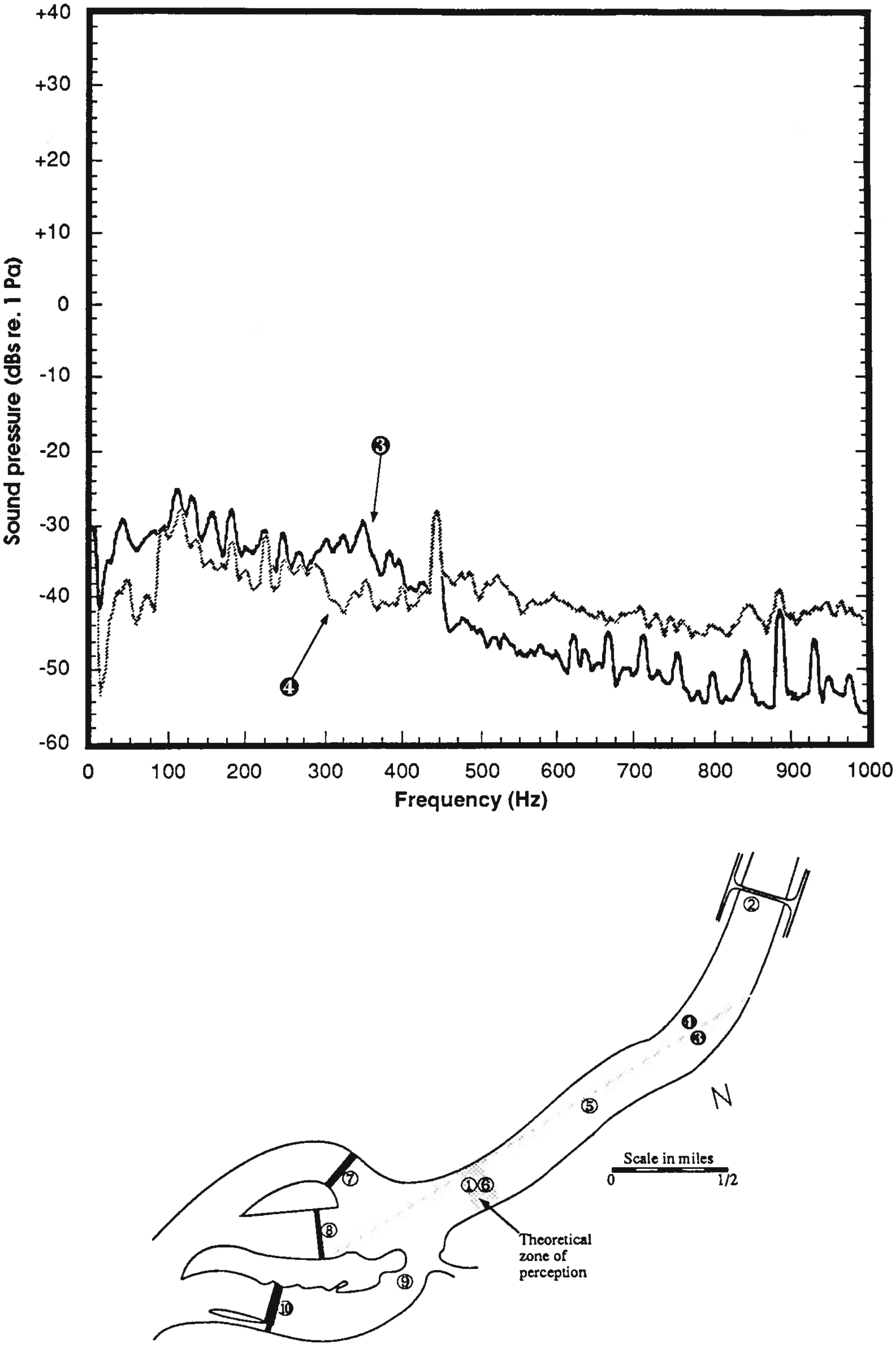


Figure 7. -- Comparison of sound spectra recorded in and out of line of sight to spillway. Blackened numbers indicate sites of measurement, faint dotted line denotes line of sight.

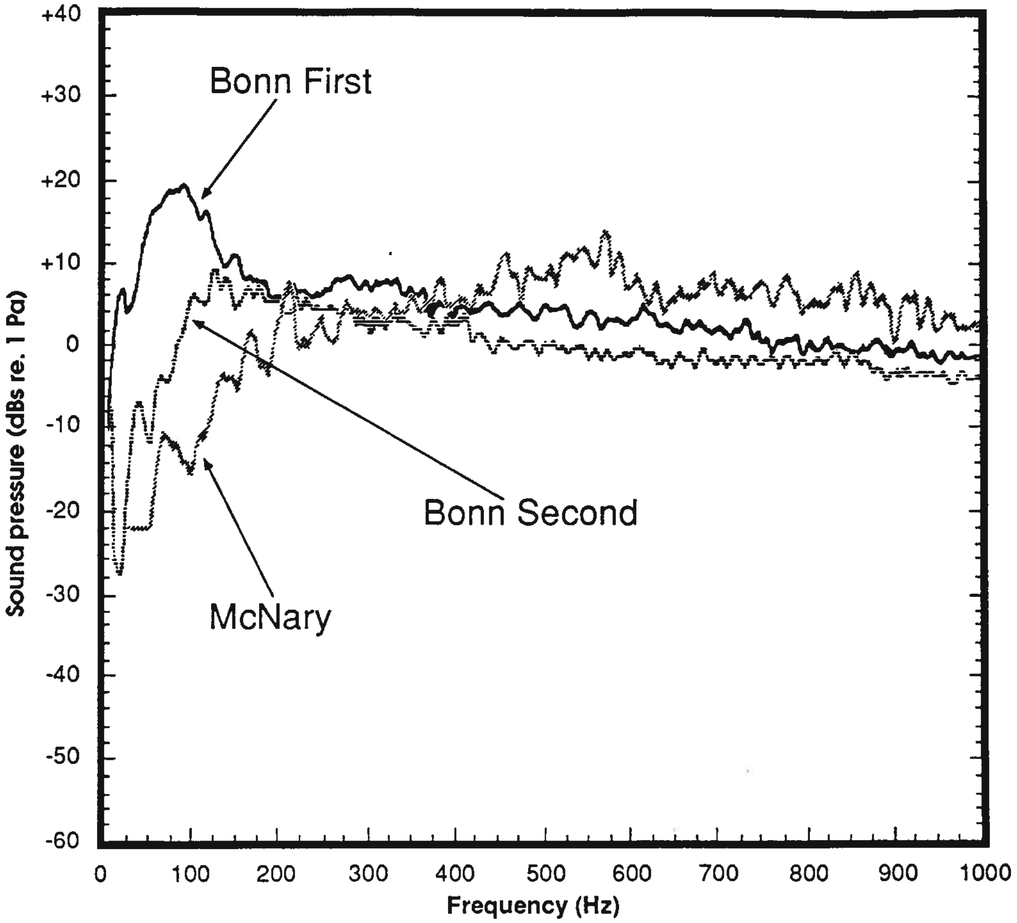


Figure 8. -- Comparison of sound spectra recorded 50 yards out in the forebay of Bonneville First and Second, and McNary projects.

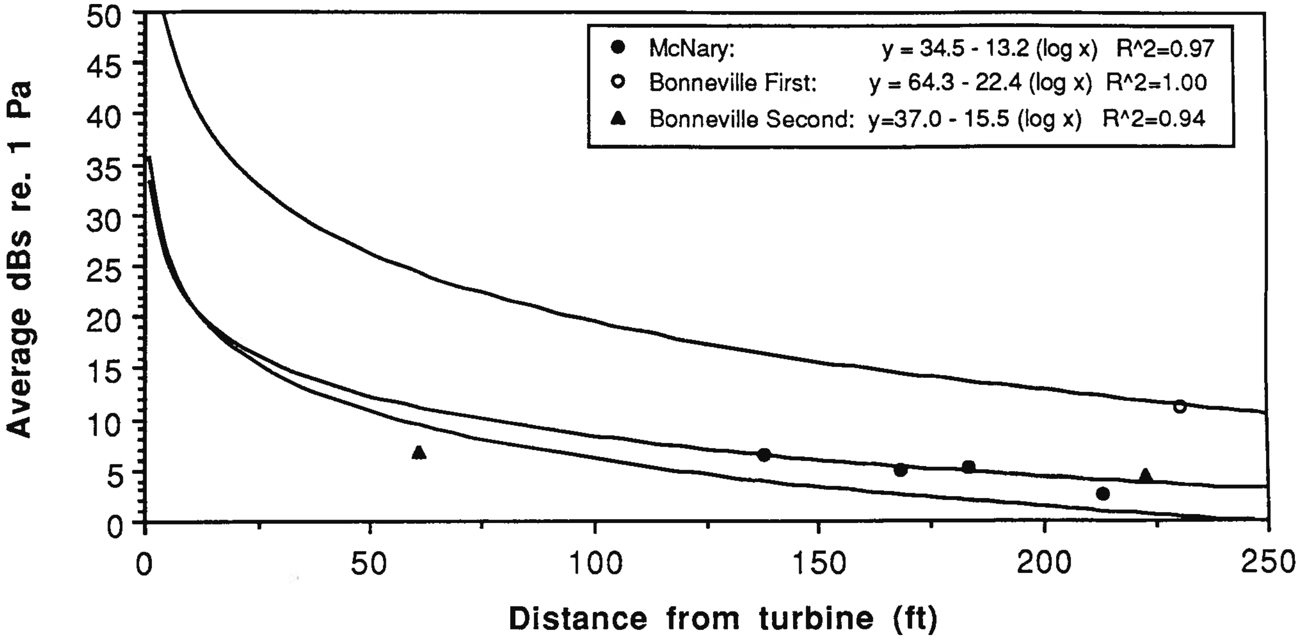


Figure 9. -- Sound propagation plots for McNary, and Bonneville First and Second Dams. Not all points are shown for each curve.

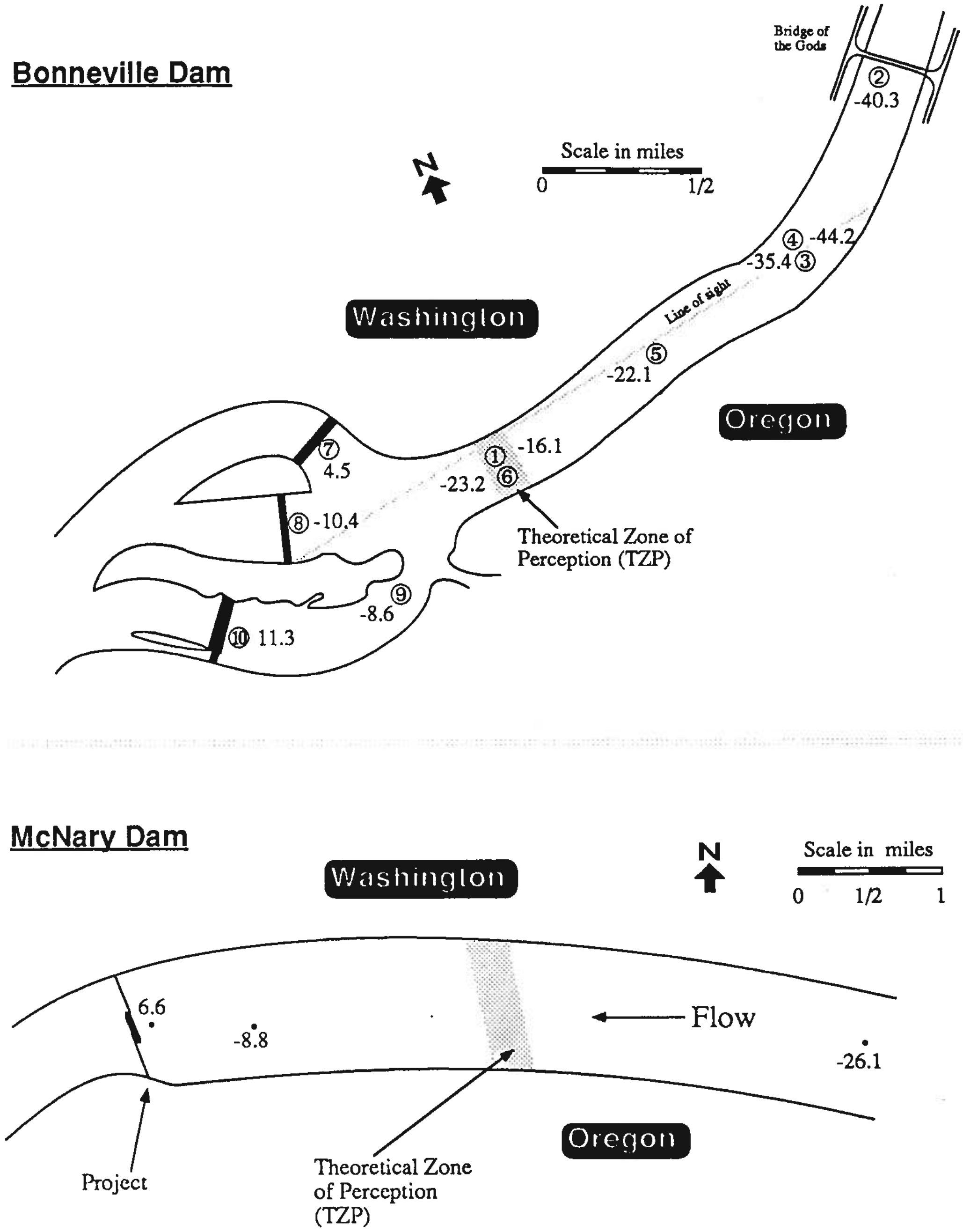


Figure 10. -- Distributions of sound fields in the forebays of Bonneville and McNary Dams. All values are in dBs re. 1 Pa.

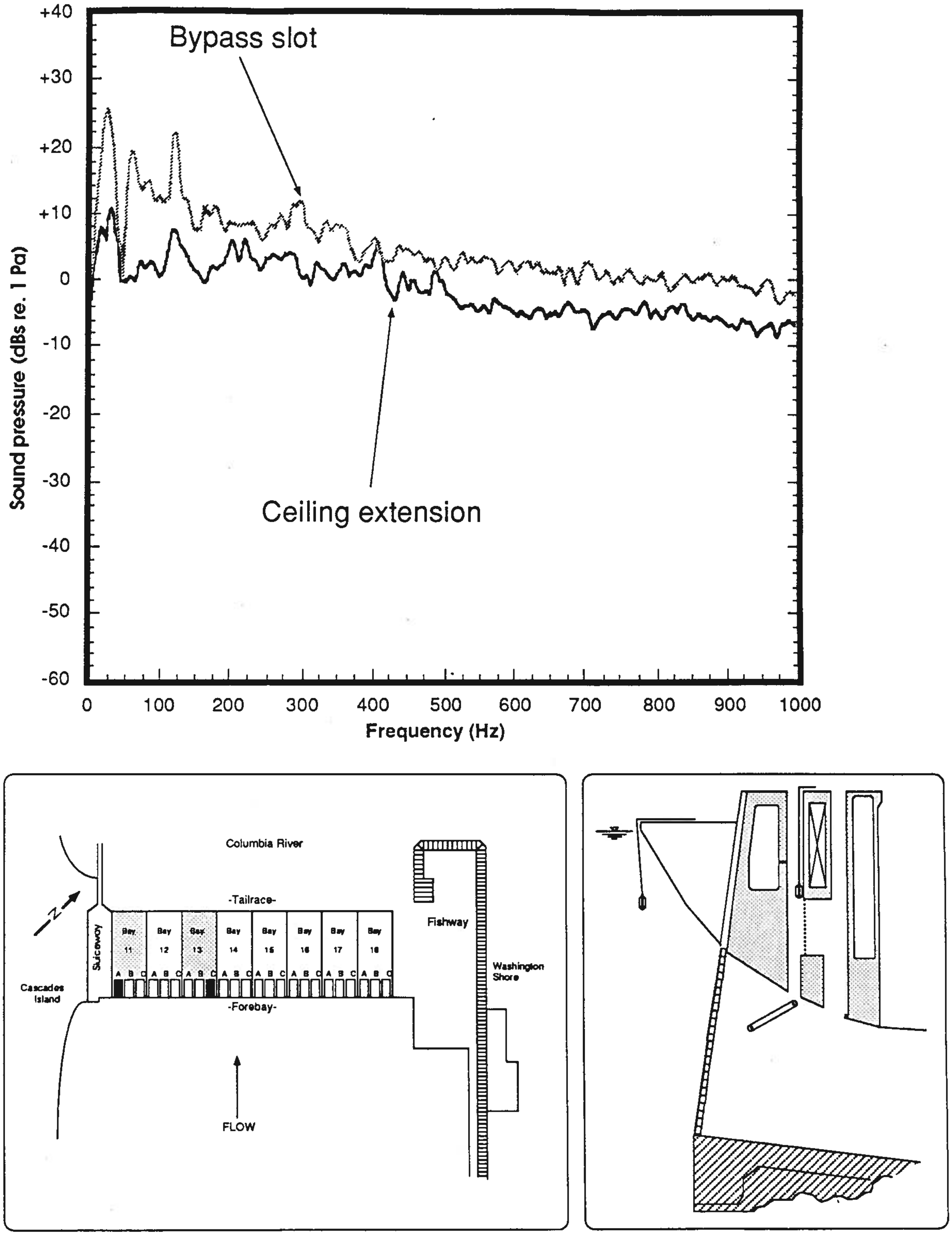


Figure 11. -- Comparison of sound spectra recorded at the bypass slot (turbine 13, gatewell C) and down the ceiling extension (turbine 11, gatewell A) at Bonneville Second.

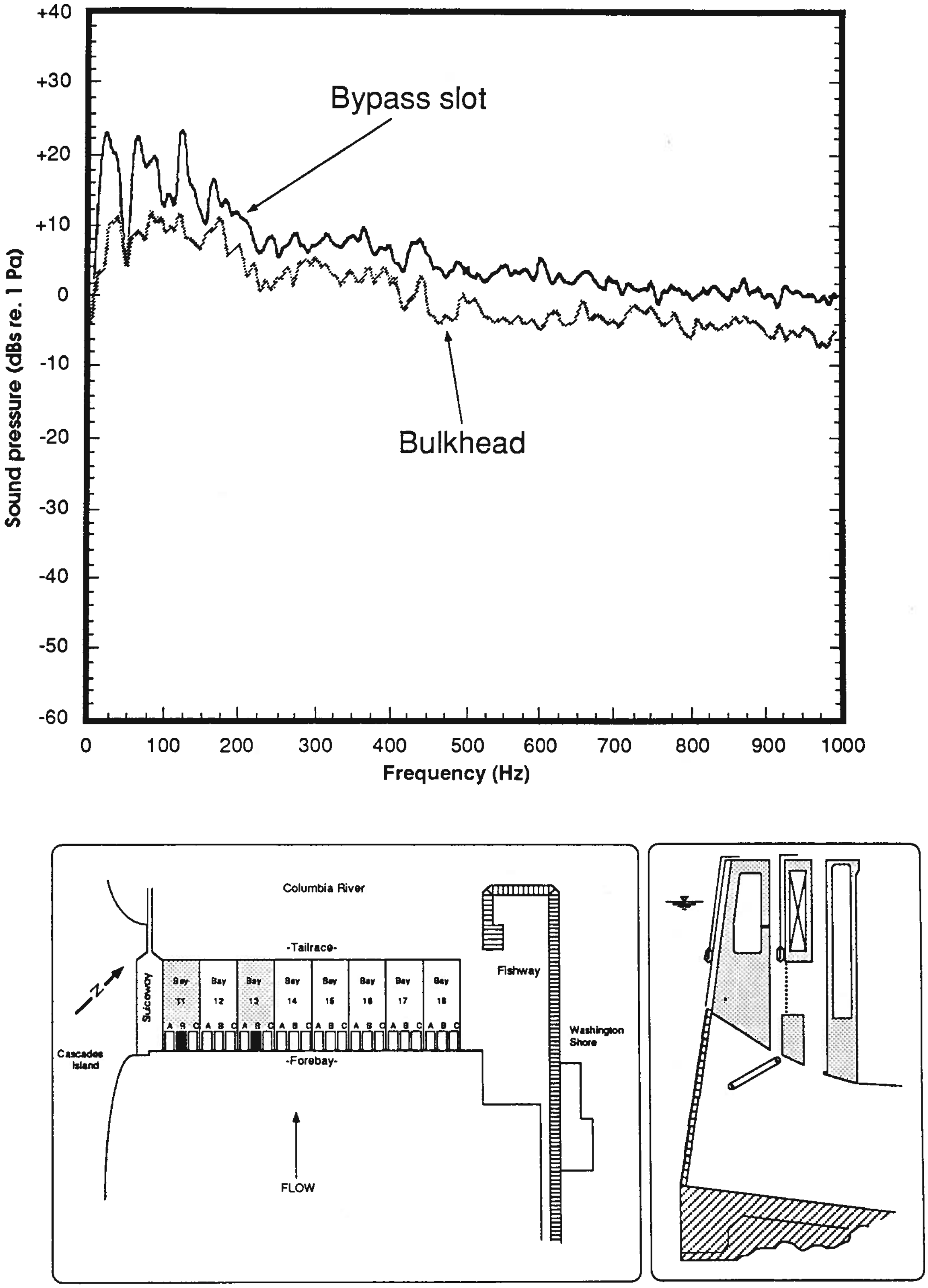


Figure 12. -- Comparison of sound spectra recorded at the bypass slot (turbine 13, gatewell B) and down the bulkhead (turbine 11, gatewell B) at Bonneville Second.

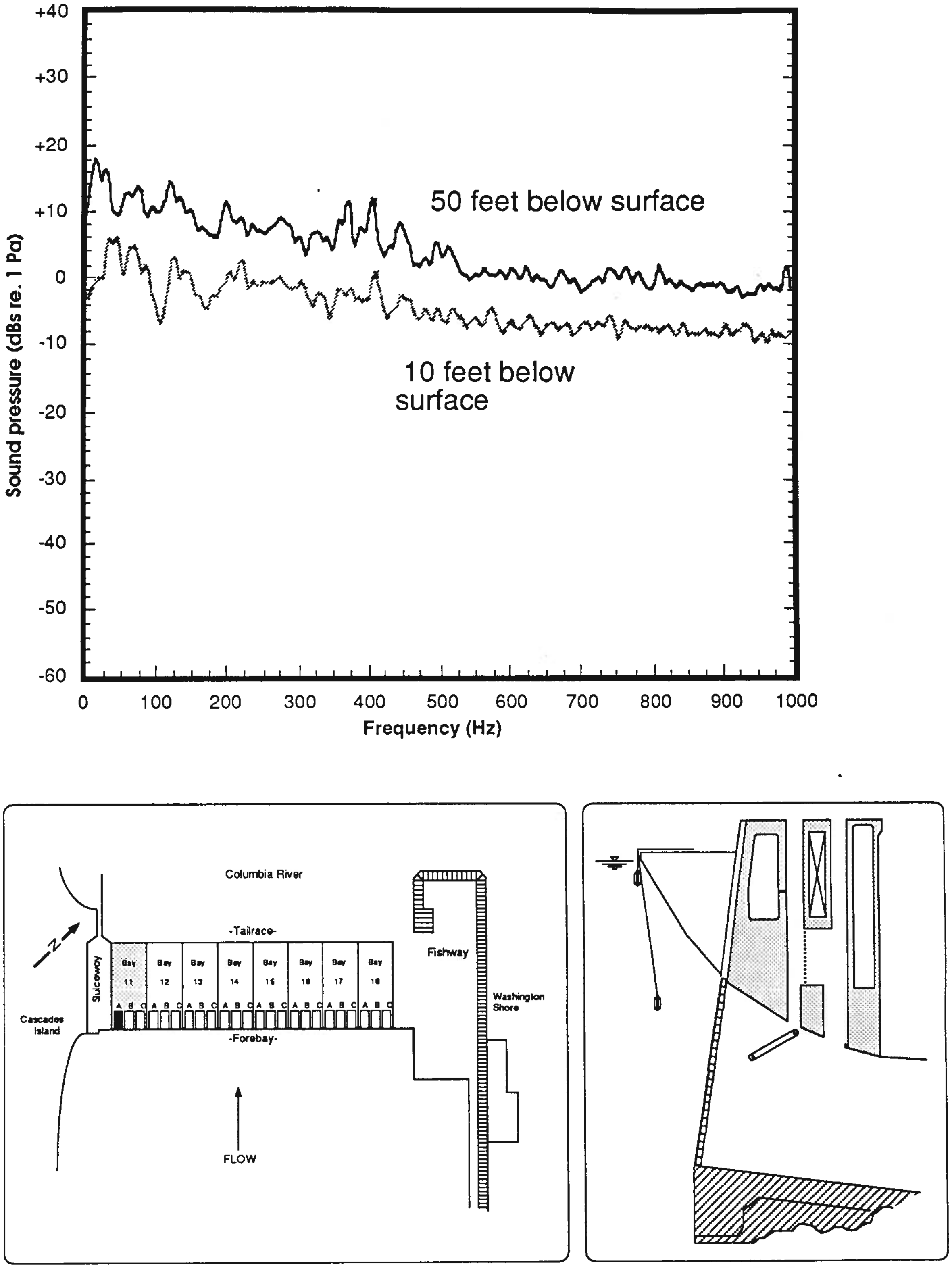


Figure 13. -- Comparison of sound spectra recorded down the ceiling extension, 10 and 50 feet below the water surface (turbine 11, gatewell A) at Bonneville Second.

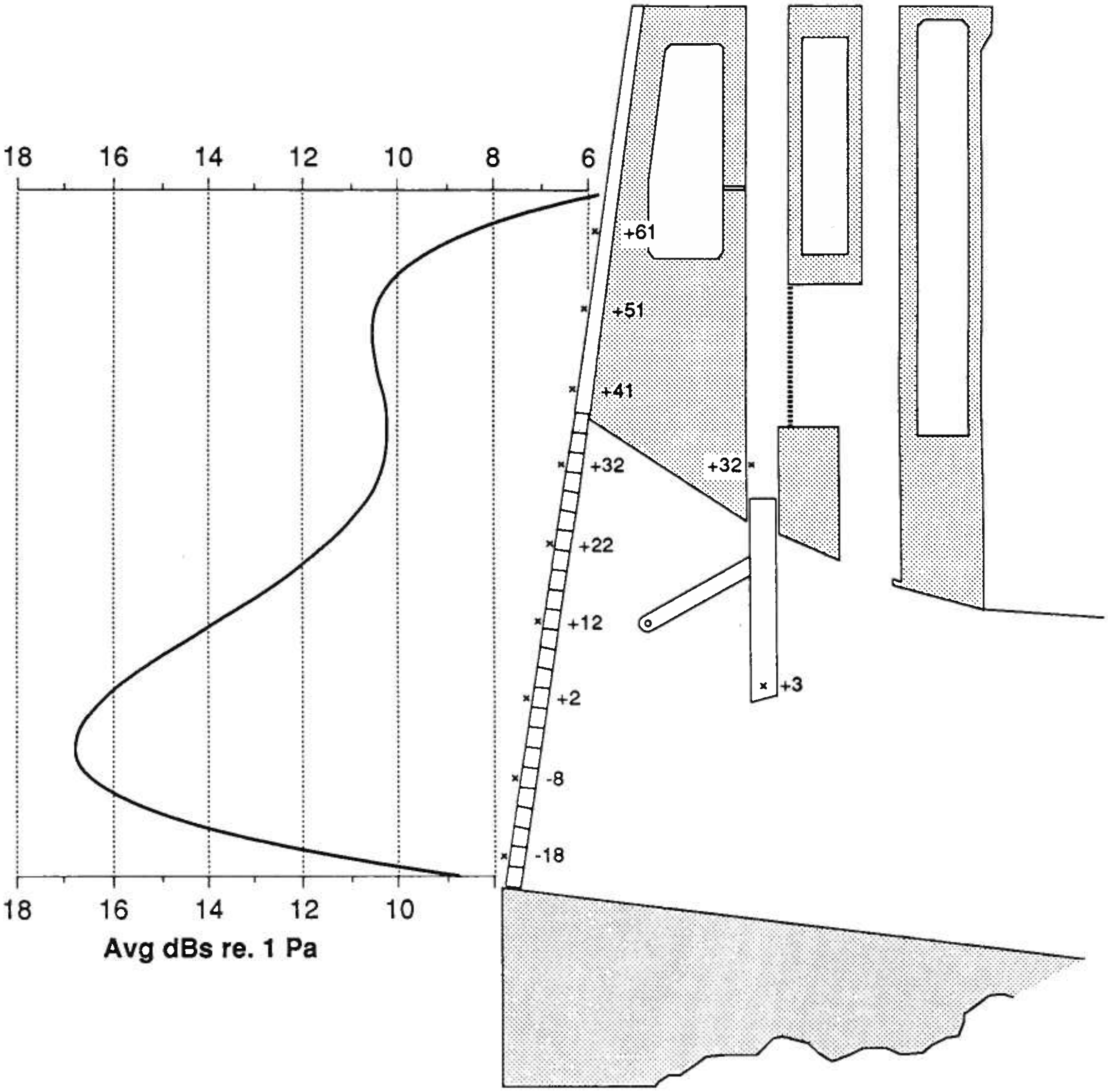


Figure 14. -- Average dBs re. 1 Pa at depths listed on the trashrack.

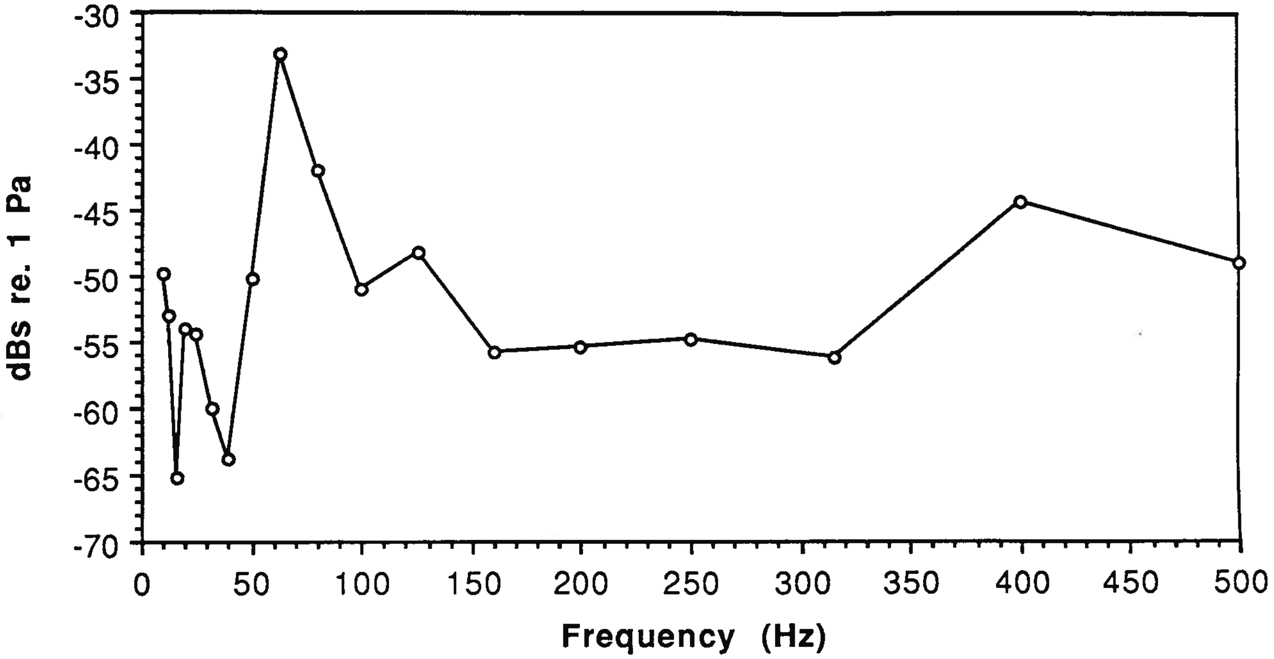


Figure 15. -- Acoustic signature at turbine hatch at Bonneville Second (Unit 15).

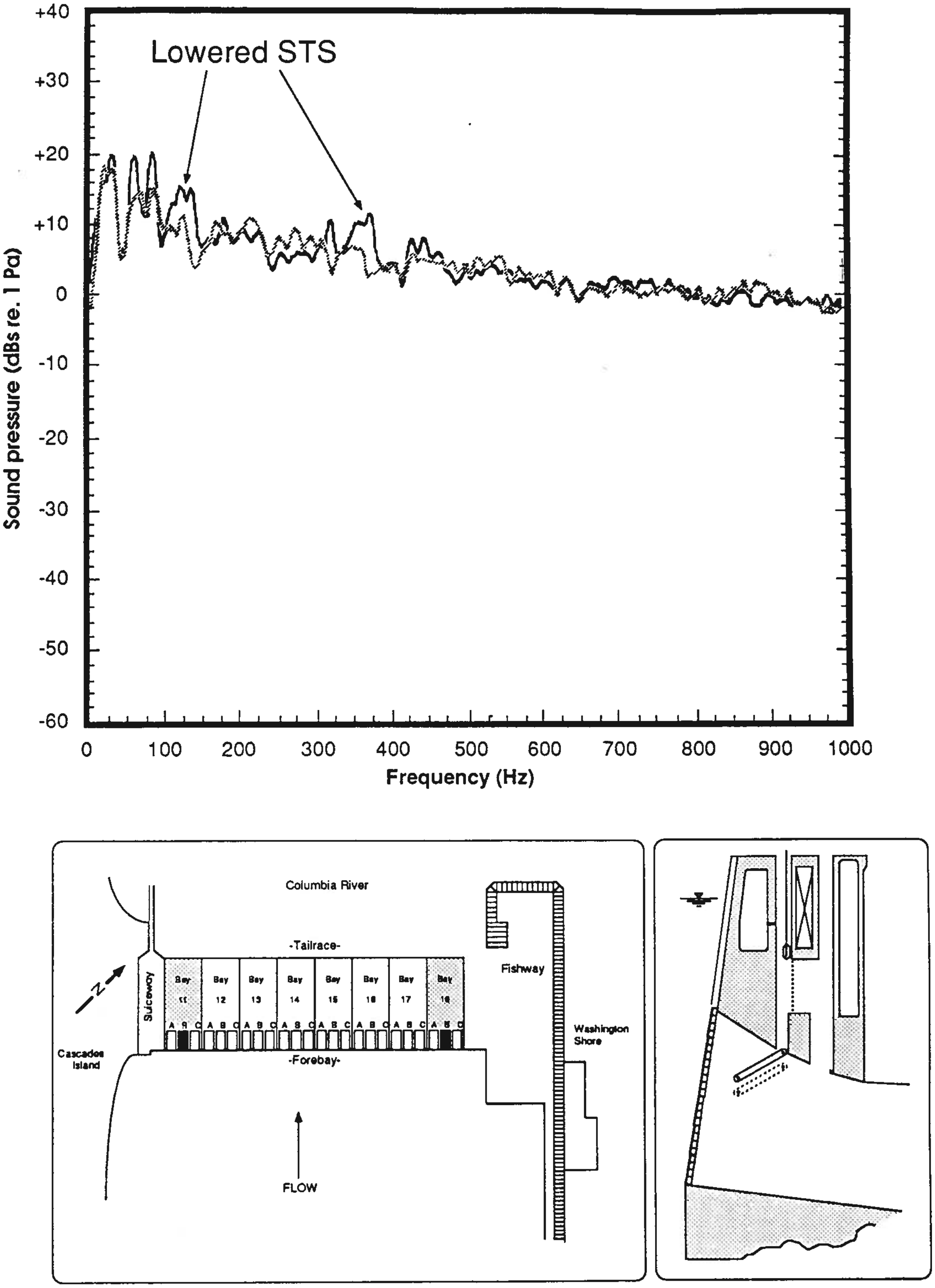


Figure 16. -- Comparison of sound spectra recorded at the bypass slot of a raised STS (turbine 18, gatewell B) and a lowered STS (turbine 11, gatewell B) at Bonneville Second.

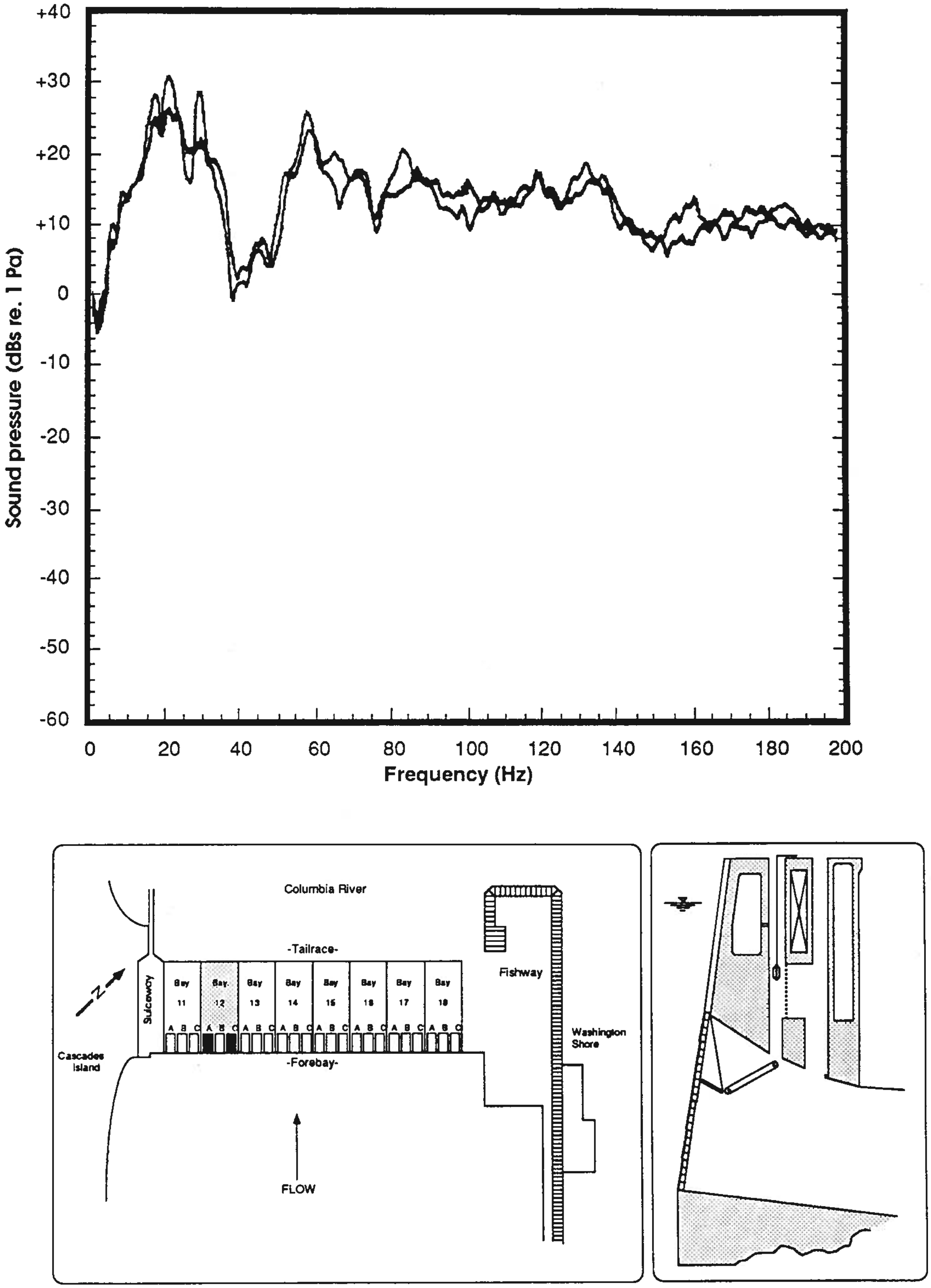


Figure 17. -- Comparison of sound spectra recorded at the bypass slot of an STS (turbine 12, gatewell C) and a bar screen (turbine 12, gatewell A) at Bonneville Second.

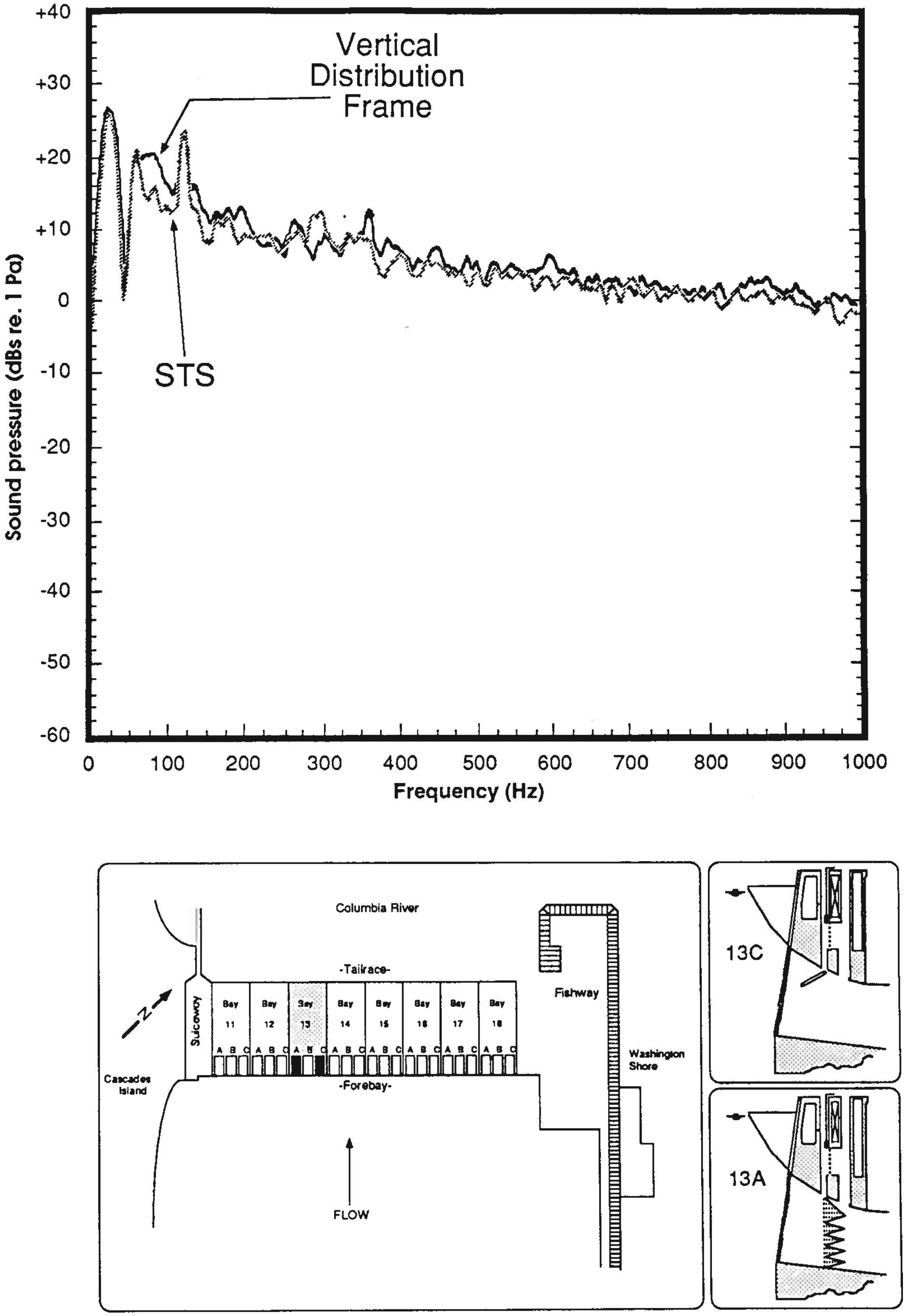


Figure 18. -- Comparison of sound spectra recorded at the bypass slot of a gatewell with a vertical distribution frame (turbine 13, gatewell A) and a gatewell with an STS (turbine 13, gatewell C) at Bonneville Second.

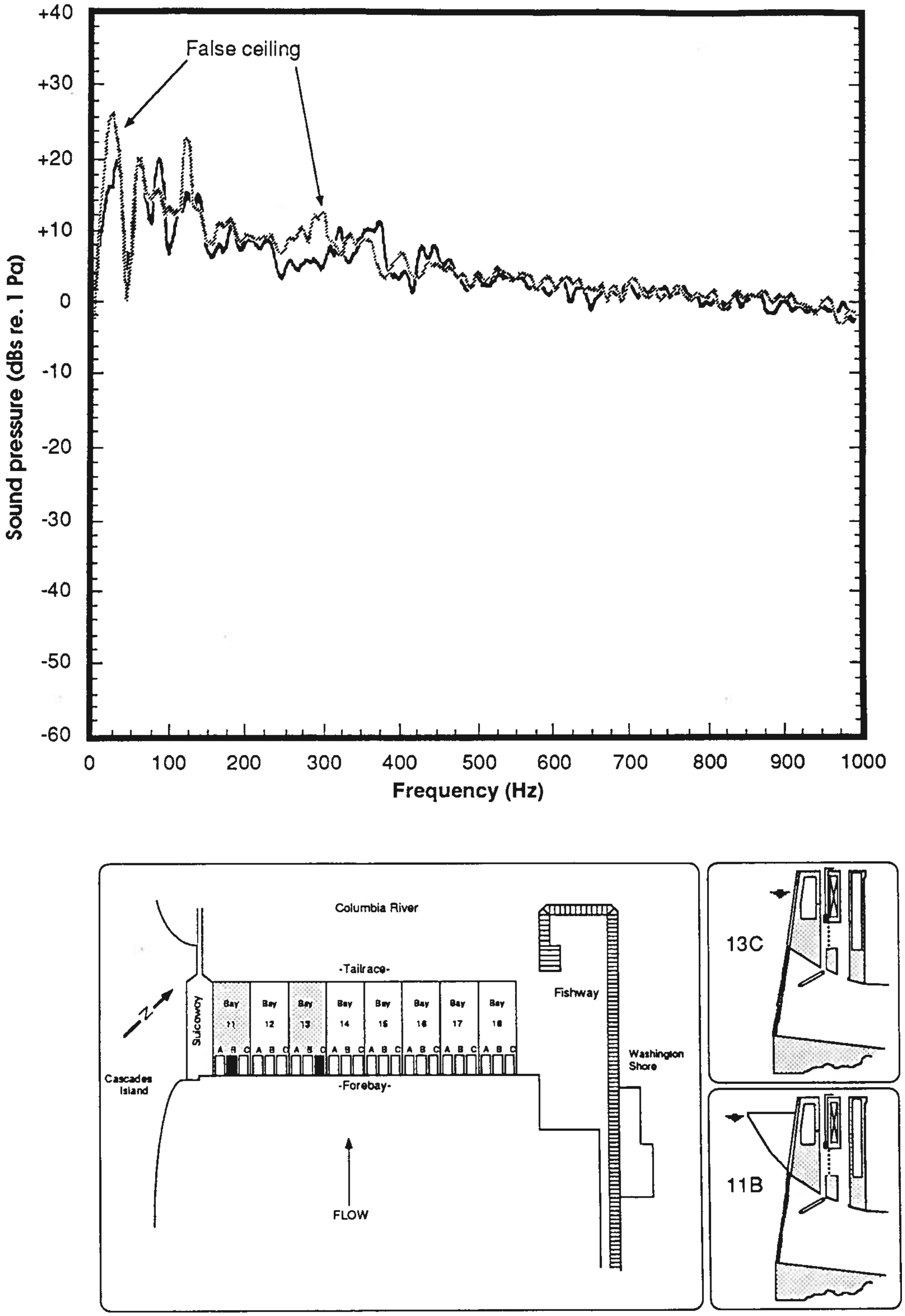


Figure 19. -- Comparison of sound spectra recorded at the bypass slot of a gatewell with a ceiling extension (turbine 13, gatewell C) and a gatewell without a ceiling extension (turbine 11, gatewell B) at Bonneville Second.

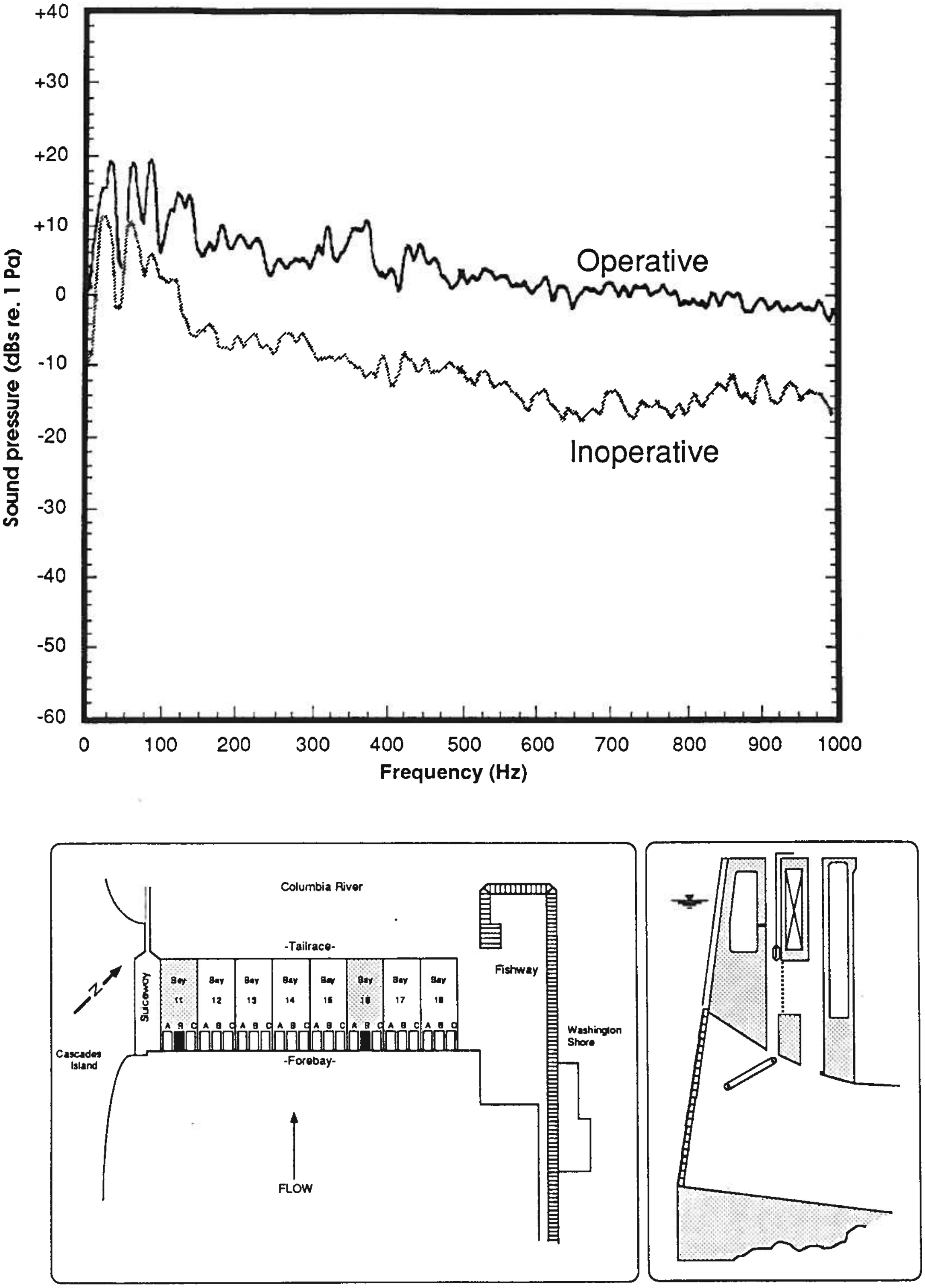


Figure 20. -- Comparison of sound spectra recorded at the bypass slot of an operating turbine (turbine 11, gatewell B) and an inoperative turbine (turbine 16, gatewell B) at Bonneville Second.

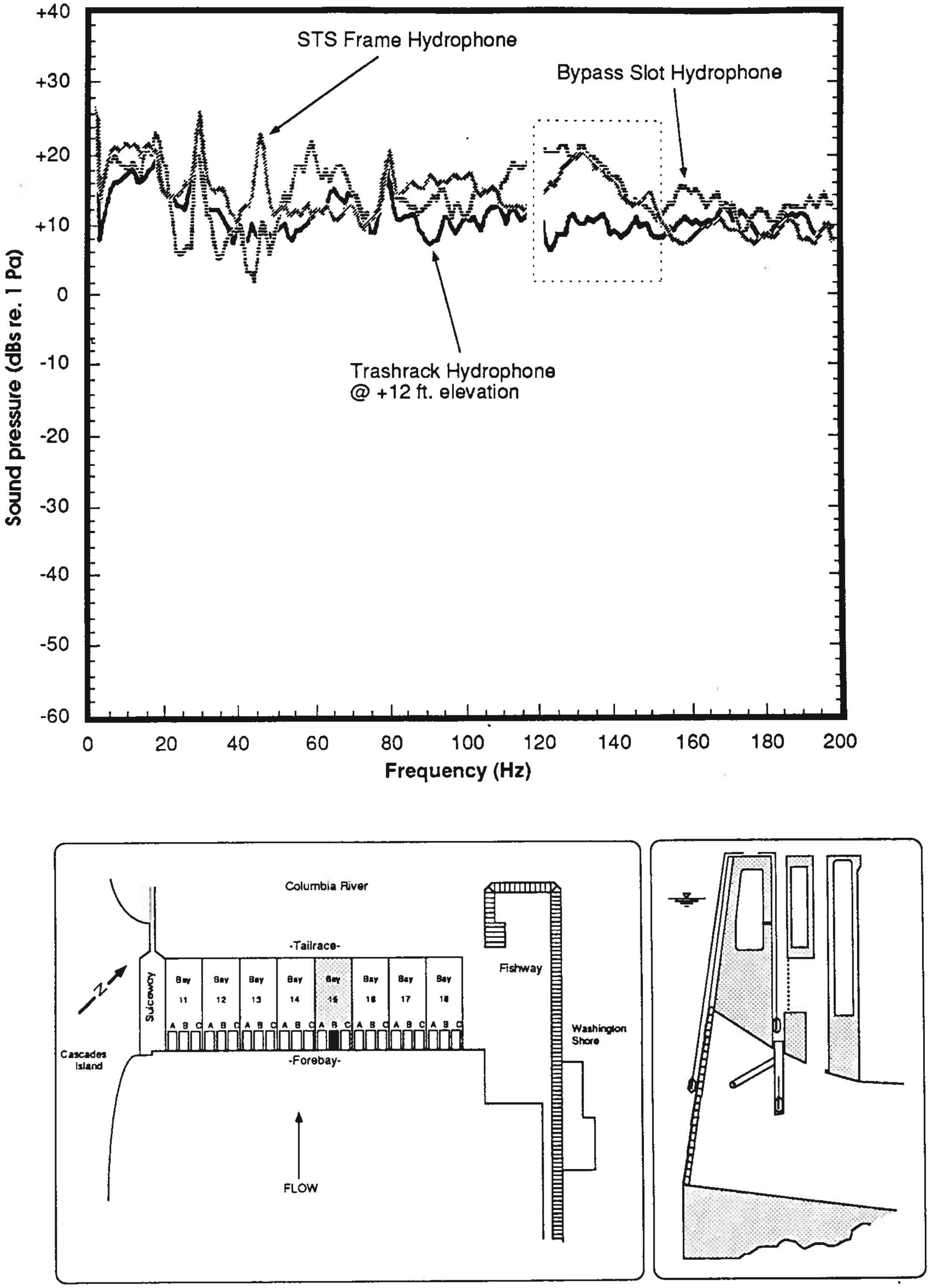


Figure 21. -- Comparison of sound spectra recorded at the bypass slot, trashrack, and down the bulkhead at Bonneville Second (turbine 15, gatewell B).

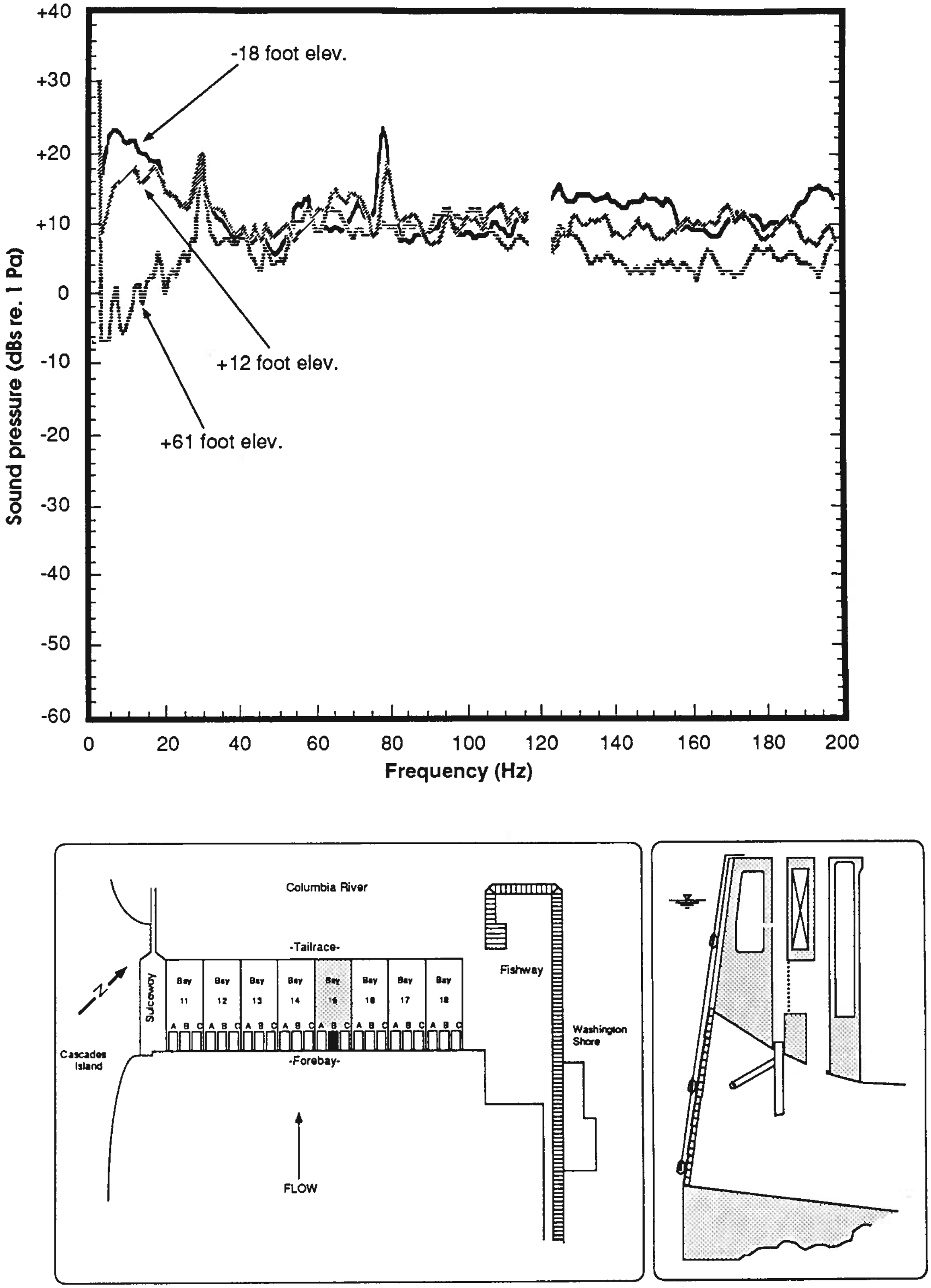


Figure 22. -- Comparison of sound spectra recorded at the +61, +12, and -18 foot elevation on the trashrack at Bonneville Second (turbine 15, gatewell B).

Dam	Code	Turb	Gate	Date	Locality	LSTS	RSTS	STR	NTR	VDF	BS	Defl	FC	Ft APP	Elev	Gain	Time	Tape	Max freq	Notes
B	1			7/13/88	Station 1												15:12	0.123	1,000	Xducer @ 25 ft, depth=89ft, lower most dolphin
B	2			7/13/88	Station 2												15:32	0.231	1,000	Bridge of the Gods, 25 ft depth Xducer
B	3			7/13/88	Station 3												15:42	0.316	1,000	Xducer @ 25ft, depth=67ft
B	4			7/13/88	Station 4												15:50	0.381	1,000	No sound from dam,depth=67ft, Xducer@25ft
B	5			7/13/88	Station 5												16:00	0.409	1,000	Off area office, spillway gates open
B	6			7/13/88	Station 6												16:08	0.476	1,000	Off dolphin, Xducer @ 25ft, closer to WA shore
B	7			7/13/88	Station 7												16:14	0.515	1,000	@ PH2
B	8			7/13/88	Station 8												16:20	0.577	1,000	Spillway, tip of island. depth=95ft
B	9			7/13/88	Station 9												16:30	0.625	1,000	In siight of PH.Xducer @ 25ft,
B	10			7/13/88	Station 10												16:35	0.656	1,000	PH1, fish ladder exit
B	26	1	B	7/12/88	bypass slot	●			●					9.5	50	6		590	1,000	
B	25	2	B	7/12/88	bypass slot	●			●					9.5	50	6		550	1,000	
B	24	3	B	7/12/88	bypass slot				●	●				9.5	50	6		500	1,000	Turbine off, no screen, fyke net in
B	23	4	B	7/12/88	bypass slot	●			●					9.5	50	6		475	1,000	
B	22	5	B	7/12/88	bypass slot	●			●					9.5	50	6	16:24	450	1,000	
B	21	6	B	7/12/88	bypass slot	●			●					9.5	50	6	16:16	425	1,000	
B	20	7	B	7/12/88	bypass slot	●			●					9.5	50	6		400	1,000	Turbine off. Spike @ 240 Hz elec interference.
B	19	8	B	7/12/88	bypass slot	●			●					9.5	50	6		370	1,000	
B	17	9	B	7/12/88	bypass slot	●			●					9.5	50	6		320	1,000	
B	18	10	B	7/12/88	bypass slot	●			●					9.5	50	6		360	1,000	
B	11	10	C	7/12/88	bypass slot	●			●					52.1	76	6	12:20	60	100	Dual plot
B	12	10	C	7/12/88	bypass slot	●			●					52.1	76	6	12:20	60	100	
B	13	10	C	7/12/88	bypass slot	●			●					52.1	76	6	12:20	60	1,000	Dual plot, 52.1/32.1 ft. above pivot pt
B	14	10	C	7/12/88	bypass slot	●			●					52.1	76	6	12:20	60	1,000	
B	15	10	C	7/12/88	bypass slot	●			●					52.1	76	6	12:20	60	10,000	
B	16	10	C	7/12/88	bypass slot	●			●					52.1	76	6	12:20	60	1E+05	
B	51	11	A	7/14/88	False Ceiling	●			●				●	26.1	40	6	16:54	1,096	1,000	Ft APP approximate
B	52	11	A	7/14/88	False Ceiling	●			●				●	11.1	55	12	16:54	1,162	1,000	Ft APP approximate
B	53	11	A	7/14/88	False Ceiling	●			●				●	21.1	45	12	16:54	1,176	1,000	Ft APP approximate
B	54	11	A	7/14/88	False Ceiling	●			●				●	31.1	35	12	16:54	1,220	1,000	Ft APP approximate
B	55	11	A	7/14/88	False Ceiling	●			●				●	41.1	25	12	16:54	1,241	1,000	Ft APP approximate
B	56	11	A	7/14/88	False Ceiling	●			●				●	51.1	15	12	16:54	1,264	1,000	Ft APP approximate
B	57	11	A	7/14/88	False Ceiling	●			●				●	61.1	5	12	16:54	1,299	1,000	Ft APP approximate
B	27	11	B	7/12/88	bypass slot	●			●					31.1	55	12	19:59	620	1,000	Before/after 20:00 hrs, Bulkhead screens, dual plot
B	28	11	B	7/12/88	bypass slot	●			●					31.1	55	6	19:59	620	1,000	S. A. code 27, except gain=6

Dam	Code	Turb	Gate	Date	Locality	LSTS	RSTS	STR	NTR	VDF	BS	Defl	FC	Ft APP	Elev	Gain	Time	Tape	Max freq	Notes
B	33	11	B	7/13/88	bypass slot	●			●					34.1	58	12	19:34	700	1,000	
B	34	11	B	7/13/88	bypass slot	●			●					34.1	58	12	19:45	771	200	Screen off
B	35	11	B	7/13/88	bypass slot	●			●					34.1	58		19:45	771	1,000	Screen off/screen on dual plot
B	36	11	B	7/13/88	bypass slot	●			●					34.1	58		19:45	771	1,000	Screen on/screen on dual plot
B	37	11	B	7/13/88	bypass slot	●			●					34.1	58	12	19:48	795	200	Screen on
B	58	11	B	7/14/88	bulkhead	●			●					19.1	43	12	17:28	1,320	1,000	
B	59	11	B	7/14/88	bulkhead	●			●					19.1	43	12	17:28	1,320	10,000	
B	60	11	B	7/14/88	bulkhead	●			●					27.1	51	12	17:28	1,359	1,000	Multiple plots
B	61	11	B	7/14/88	bulkhead	●			●					29.1	53		17:28	1,359	1,000	
B	62	11	B	7/14/88	bulkhead	●			●					39.1	63	12	17:45	1,373	1,000	
B	63	11	B	7/14/88	bulkhead	●			●					41.1	65	12	17:45	1,373	10,000	
B	64	11	B	7/14/88	bulkhead	●			●					49.1	73	12	17:45	1,428	1,000	
B	65	11	B	7/14/88	bulkhead	●			●					52.1	76	12	17:45	1,452	1,000	
B	66	11	B	7/14/88	bulkhead	●			●					52.1	76	12	17:45	1,452	10,000	
B	38	12	A	7/13/88	bypass slot	●		●				●		34.1	58	12	20:02	810	1,000	
B	67	12	A	7/14/88	bypass slot			●			●	●		34.1	58	12	20:30	1,474	200	
B	68	12	A	7/14/88	bypass slot			●			●	●		34.1	58	12	20:30	1,474	1,000	
B	39	12	B	7/13/88	bypass slot	●		●				●	●	34.1	58	12	20:08	850	1,000	
B	69	12	B	7/14/88	bypass slot			●			●	●	●	34.1	58	12	20:37	1,505	200	
B	70	12	B	7/14/88	bypass slot			●			●	●	●	34.1	58	12	20:37	1,505	1,000	
B	82	12	B	7/14/88	bypass slot			●			●	●	●	6.1	30	12	21:16	1,652	1,000	
B	83	12	B	7/14/88	bypass slot			●			●	●	●	6.1	30	12	21:16	1,652	200	
B	29	12	C	7/12/88	bypass slot	●		●				●		34.1	58	12	20:17	675	100	
B	30	12	C	7/12/88	bypass slot	●		●				●		34.1	58	12	20:17	675	1,000	Double plot
B	31	12	C	7/12/88	bypass slot	●		●				●		34.1	58	6	20:17	675	1,000	Bar screen not yet lowered
B	32	12	C	7/12/88	bypass slot	●		●				●		34.1	58	12	20:17	675	10,000	
B	40	12	C	7/13/88	bypass slot	●		●				●		34.1	58	12	20:13	875	1,000	
B	71	12	C	7/14/88	bypass slot	●		●				●		34.1	58	12	20:42	1,530	200	
B	72	12	C	7/14/88	bypass slot	●		●				●		34.1	58	12	20:42	1,530	1,000	
B	80	12	C	7/14/88	bypass slot	●		●				●		6.1	30	12	21:10	1,610	200	
B	81	12	C	7/14/88	bypass slot	●		●				●		6.1	30	12	21:10	1,610	1,000	
B	41	13	A	7/13/88	bypass slot			●		●			●	34.1	58	12	20:17	903	200	
B	42	13	A	7/13/88	bypass slot			●		●			●	34.1	58	12	20:17	903	1,000	
B	73	13	A	7/14/88	bypass slot			●		●			●	34.1	58	12	20:47	1,555	200	
B	74	13	A	7/14/88	bypass slot			●		●			●	34.1	58	12	20:47	1,555	500	

Dam	Code	Turb	Gate	Date	Locality	LSTS	RSTS	STR	NTR	VDF	BS	Defl	FC	Ft APP	Elev	Gain	Time	Tape	Max freq	Notes
B	**75**	13	A	7/14/88	bypass slot			●		●			●	34.1	58	12	20:47	1,555	1,000	
B	**84**	13	A	7/14/88	bypass slot			●		●			●	6.1	30	12	21:23	1,689	200	
B	**85**	13	A	7/14/88	bypass slot			●		●			●	6.1	30	12	21:23	1,689	1,000	
B	**43**	13	B	7/13/88	bypass slot	●			●					34.1	58		20:27	926	200	Dual plot, mainset and portable
B	**44**	13	B	7/13/88	bypass slot	●			●					34.1	58	12	20:27	926	1,000	
B	**76**	13	B	7/14/88	bypass slot	●			●					34.1	58	12	20:56	1,580	200	Marker @ 60 Hz
B	**77**	13	B	7/14/88	bypass slot	●			●					34.1	58		20:56	1,580	200	
B	**78**	13	B	7/14/88	bypass slot	●			●					34.1	58	12	20:56	1,580	1,000	
B	**79**	13	B	7/14/88	bypass slot	●			●					34.1	58	12	20:56	1,580	1,000	
B	**45**	13	C	7/13/88	bypass slot	●			●				●	34.1	58	12	20:32	952	1,000	
B	**86**	15	B	3/29/89	trashrack	●			●					-41.8	-17.94	24	11:17	751	200	Turbine off, 64 avg's on spec analyzer
B	**87**	15	B	3/29/89	trashrack	●			●					-41.8	-17.94	12	11:23	866	200	Turbine on, 64 avg's on spec analyzer
B	**88**	15	B	3/29/89	trashrack	●			●					-31.9	-8.04	12	11:50	1,072	200	
B	**89**	15	B	3/29/89	trashrack	●			●					-31.9	-8.04	12	12:13	1,280	1,000	
B	**90**	15	B	3/29/89	trashrack	●			●					-22.0	1.87	12	12:50	1,400	200	
B	**91**	15	B	3/29/89	trashrack	●			●					-12.1	11.77	12	12:55	1,434	200	
B	**92**	15	B	3/29/89	trashrack	●			●					-2.2	21.67	12	12:59	1,467	200	
B	**93**	15	B	3/29/89	trashrack	●			●					7.7	31.57	12	13:04	1,523	200	
B	**94**	15	B	3/29/89	trashrack	●			●					17.6	41.52	12	13:10	1,570	200	
B	**95**	15	B	3/29/89	trashrack	●			●					27.5	51.38	12	13:14	1,620	200	
B	**96**	15	B	3/29/89	trashrack	●			●					37.4	61.29	12	13:19	1,672	200	
B	**97**	15	B	3/29/89	STS	●			●					-20.6	3.27					position of STS hydrophone for code 86-96
B	**98**	15	B	3/29/89	Bypass	●			●					8.1	32					position of bypass hydrophone for code 86-96
B	**46**	16	B	7/13/88	bypass slot	●			●					34.1	58	12	20:39	975	1,000	Turbine off
B	**47**	18	A	7/13/88	bypass slot		●		●					34.1	58	12	20:48	1,001	1,000	Bad data, object struck hydrophone
B	**50**	18	A	7/13/88	bypass slot		●		●					34.1	58	12	21:02	1,078	1,000	No streaming
B	**48**	18	B	7/13/88	bypass slot		●		●					34.1	58	12	20:53	1,025	1,000	Same as code 50
B	**49**	18	C	7/13/88	bypass slot		●		●					34.1	58	12	20:57	1,050	1,000	Same as code 50
LG	**27**			8/29/88	Ladder										730	36	16:16	2,506	1,000	last chamber, highest elev, right @ orifice, each.....
LG	**28**			8/29/88	Ladder										730	36	16:20	2,531	200	......chamber is 8' deep, xducer 4' deep.
LG	**29**			8/29/88	Ladder										730	36	16:23	2,575	200	2nd to last chamber, gurgling sound
LG	**30**			8/29/88	Ladder										730	36	16:27	2,601	1,000	xducer scrapes against wall
LG	**31**			8/29/88	Ladder										730	36	16:31	2,643	1,000	inlet to last champer-12'from it, forebay side
LG	**32**			8/29/88	Ladder										730	36	16:34	2,650	200	same scenario as code 31. Tape off @ 2685. 1635
LG	**25**	2	B	8/29/88	Bypass									24.5	660	12	15:38	2,458	1,000	turbine off

Dam	Code	Turb	Gate	Date	Locality	LSTS	RSTS	STR	NTR	VDF	BS	Defl	FC	Ft APP	Elev	Gain	Time	Tape	Max freq	Notes
LG	26	2	B	8/29/88	Bypass									24.5	660	12	15:40	2,479	200	turbine off
LG	1	3	B	8/29/88	Bypass									24.5	660	0	13:45		250	
LG	2	3	B	8/29/88	Bypass									24.5	660	0	13:55		1,000	
LG	3	3	B	8/29/88	Bypass									24.5	660	0	14:00	1,825	200	
LG	4	3	B	8/29/88	Bypass									24.5	660	0	14:02	1,843	10,000	
LG	5	3	B	8/29/88	Bypass									24.5	660	0	14:04	1,852	1E+05	
LG	6	3	B	8/29/88	Bypass									24.5	660	6	14:05	1,869	1E+05	switch m gain to 6 dB
LG	7	3	B	8/29/88	Bypass									24.5	660	6	14:08	1,891	200	2 spectra (same) on top of eachother-peak @ 9 Hz
LG	8	3	B	8/29/88	Bypass									73.24	709.66	6	14:18	1,955	200	Overlay spectra from 24.5 to 73.5 (code 7 + 9)
LG	9	3	B	8/29/88	Bypass									73.5	709	6	14:21		200	Only 709' spectra, same data as code 8
LG	10	3	B	8/29/88	Bypass									73.5	709	6	14:23	2,080	1,000	
LG	11	3	B	8/29/88	Bypass									90.5	726	6	14:25	2,028	1,000	
LG	12	3	B	8/29/88	Bypass									90.5	726	6	12:28	2,049	200	
LG	13	3	B	8/29/88	Bypass									90.5	726	12	14:32	2,079	200	gain up to 12 dB-compare w/code 12 for diff
LG	14	3	B	8/29/88	Bypass									24.5	660	12	14:34	2,109	100	2150' on tape-lowered xducer to 24.5
LG	15	3	B	8/29/88	Bypass									24.91	660.726	12	14:41	2,163	100	overlay spectra from 24.5 & 90.5 (code 14 + 16)
LG	16	3	B	8/29/88	Bypass									90.5	726	12	14:41		100	
LG	17	3	B	8/29/88	Bulkhead									60.5	696	12	15:10	2,260	1,000	
LG	18	3	B	8/29/88	Bulkhead									60.5	696	12	15:11	2,281	200	Tape @ 2295-move xducer up to 60.5
LG	19	3	B	8/29/88	Bulkhead									60.5	696	12	15:14	2,325	200	
LG	20	3	B	8/29/88	Bulkhead									60.5	696	12	15:17	2,335	1,000	
LG	21	3	B	8/29/88	Bulkhead									80.5	716	12	15:20	2,365	1,000	
LG	22	3	B	8/29/88	Bulkhead									80.5	716	12	15:22	2,382	200	
LG	23	3	B	8/29/88	Bulkhead									90.5	726	12	15:26	2,415	200	
LG	24	3	B	8/29/88	Bulkhead									90.5	726	12	15:27	2,443	1,000	
M	30			8/30/88	FF site #1										314	10.09	10:45		200	water depth=63'
M	31			8/30/88	FF site #1										314	10.09	10:45		1,000	
M	32			8/30/88	FF site #1										314	10.09	10:45		1,000	
M	33			8/30/88	FF site #1										314	10.09	10:51		200	
M	34			8/30/88	FF site #1										314	10.09	10:51		200	
M	35			8/30/88	FF site #1										314	10.09	10:51		200	
M	36			8/30/88	FF site #1										314	10.09	10:51		200	
M	37			8/30/88	FF site #1										314	10.09	10:53		200	
M	38			8/30/88	FF site #1										314	10.09	10:54		200	
M	39			8/30/88	FF site #1										314	10.09	10:55		200	

Dam	Code	Turb	Gate	Date	Locality	LSTS	RSTS	STR	NTR	VDF	BS	Defl	FC	Ft APP	Elev	Gain	Time	Tape	Max freq	Notes
M	40			8/30/88	FF site #1										314	10.09	10:56		200	
M	41			8/30/88	FF site #1										314	10.09	10:56		200	water depth=106'
M	42			8/30/88	FF site #1										314	10.09			200	superimposition of codes 33-41
M	43			8/30/88	FF site #1										314	10.09			1,000	superimposition of codes 33-41
M	44			8/30/88	FF site #1										314	10.09			200	
M	45			8/30/88	FF site #2										314	39.02	11:09		200	
M	46			8/30/88	FF site #2										314	39.02	11:09		1,000	
M	47			8/30/88	FF site #3										314	17.5	11:22		200	
M	48			8/30/88	FF site #3										314	17.5	11:23		1,000	
M	49			8/30/88	FF site #3										314	17.5	11:24		1,000	waterfall diagram
M	50			8/30/88	FF site #4										314	15.53	11:35		1,000	
M	51			8/30/88	FF site #4										314	15.53	11:35		200	
M	52			8/30/88	FF site #4										314	15.53	11:35		200	from close in to far field, new data
M	1	2	B	8/30/88	Bypass									12.2	286	12	12:50		200	not recorded on tape
M	2	2	B	8/30/88	Bypass									12.2	286	12	12:58		1,000	not recorded on tape
M	3	2	B	8/30/88	Bypass									12.2	286	12	13:00		400	not recorded on tape, overlay w/code 4
M	4	2	B	8/30/88	Bypass									12.2	286	12	13:03		400	not recorded on tape, overlay w/code 3 & code 5,6,7
M	5	2	B	8/30/88	Bypass									12.2	286	12	13:05		400	not recorded on tape, overlay w/code 4,6,7
M	6	2	B	8/30/88	Bypass									12.2	286	12	13:07		400	not recorded on tape, overlay w/code 4,5,7
M	7	2	B	8/30/88	Bypass									12.2	286	12	13:08		400	not recorded on tape, overlay w/code 4,5,6
M	8	2	B	8/30/88	Bypass									12.2	286	12	13:10		10,000	not recorded on tape
M	9	2	B	8/30/88	Bypass									12.2	286	12	13:11		1E+05	start recording on tape
M	10	2	B	8/30/88	Bypass									42.2	316	12	13:16		200	
M	11	2	B	8/30/88	Bypass									42.2	316	12	13:19		1,000	
M	12	2	B	8/30/88	Bypass									42.2	316	12	13:20		400	
M	13	2	B	8/30/88	Bypass									62.2	336	12	13:23		400	
M	14	2	B	8/30/88	Bypass									62.2	336	12	13:25		200	
M	15	2	B	8/30/88	Bypass									62.2	336	12	13:28		1,000	
M	16	2	B	8/30/88	Bypass									12.2	286	12	13:31		400	repeat of 286 level in code 1-8 since not recorded
M	17	2	B	8/30/88	Bypass									22.2	296	12	14:23		400	un-socked xducer, overlay w/code 18
M	18	2	B	8/30/88	Bypass									22.2	296	12	14:27		400	socked xducer, overlay w/code 17
M	19	2	B	8/30/88	Bypass									22.2	296	12	14:30		1,000	un-socked xducer, overlay w/code 20
M	20	2	B	8/30/88	Bypass									22.2	296	12	14:31		1,000	socked xducer, overlay w/code 19
M	21	2	B	8/30/88	Bypass									22.2	296	12	14:34		1,000	socked xducer
M	22	2	B	8/30/88	Bypass									22.2	296	12	14:43		1,000	former socked xducer un-socked for ctrl

Dam	Code	Turb	Gate	Date	Locality	LSTS	RSTS	STR	NTR	VDF	BS	Defl	FC	Ft APP	Elev	Gain	Time	Tape	Max freq	Notes	
M	**23**	2	B	8/30/88	**Bypass**									22.2	296	12	14:45		1,000	former un-socked xducer still un-socked for ctrl	
M	**24**	2	B	8/30/88	**Bypass**									22.2	296	-12	15:02		1,000	ITC xducer, ITC/B&K on fram, overlay w/code 25	
M	**25**	2	B	8/30/88	**Bypass**									22.2	296	12	15:04		1,000	B&K xducer, overlay w/code 24	
M	**26**	2	B	8/30/88	**Bypass**									22.2	296	12	15:08		200	B&K xducer, overlay w/code 27 and 29	
M	**27**	2	B	8/30/88	**Bypass**									22.2	296	-12	15:11		200	ITC xducer, overlay w/code 26	
M	**28**	2	B	8/30/88	**Bypass**									22.2	296		15:17		200	o-lay w/code26,28. Bell&Howell=3556=535 on Sony	
M	**29**	2	B	8/30/88															2,000	-40 dB cal tone, -37.74 @ 1000 Hz, 0-lay 26,28	